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Volume 8, Number 6

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Cover:
Photographer Dean Garner pulled some Gs as he shot this self-portrait from the rear seat of an F-16.

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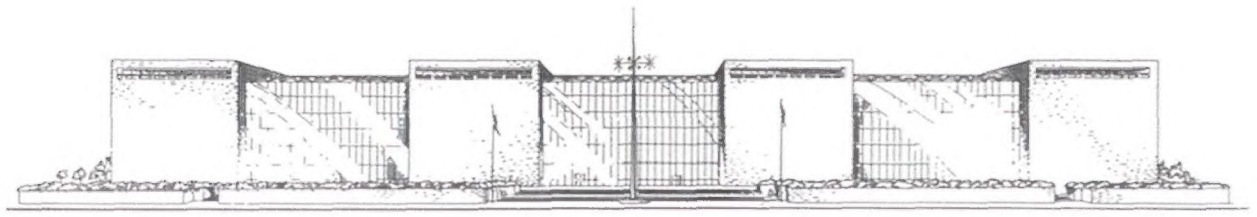

Losing Friends?

The influential German weekly *Die Zeit* recently carried an article by Reimar Lüst, until 1990 the director general of the European Space Agency. He writes about the agreement between Russia and the United States, concluded in the past few weeks, to jointly build a manned space station.

The Europeans have long been loyal partners working with the United States toward a common space station. Lüst's comments, therefore, carry weight when he writes: "To be sure, five years ago, the Americans signed a similar agreement with the Europeans, Japan and Canada, to also build a shared space station. President Reagan had first extended an invitation in 1984. Contrary to the spirit of that agreement, the Americans [have now] failed to consult their original partners about the collaboration with the Russians. They held notification by telephone, 24 hours before the official news announcement in Washington, to be perfectly adequate."

Lüst adds, "The European Space Agency, ESA, will now have to come to terms with this new situation."

The Europeans do not object to the newly forged partnership with Russia, which they consider a logical step. Their complaint is that the new union was reached without their being consulted, when they know that it will entail further redesigns and probably added costs to them at a time when they already are under political and financial pressure to reconsider their priorities in space.

The European frustrations are understandable, though such slights are in no way intentional. The problem on the American side is that negotiations on space collaboration involve an intricate interplay between the White House, Congress, the state department, and NASA, and consultation abroad is difficult until all agree on a course of action.

But this is not the first time that we have announced a change in the ground rules to the Europeans, whose consternation each time reaches new heights. The day may come when they no longer feel their best interests lie in working with a nation they consider an unreliable partner.

We have to recognize that, in the long run, we may need the Europeans more than they need us. Even if ESA's budget today is one-quarter that of NASA's, ESA's skills and self-sufficiency are rapidly growing. With considerable pride, Lüst refers to the Ariane family of rockets, which, he writes, "has gained more than half the world market share for non-military, commercial launches, having lofted 90 satellites in 61 launches since 1979." And Ariane 5, the next-generation heavy-lift vehicle about to come on line, may further solidify that lead and convince the Europeans that they are better off seeking their own, separate fortunes in space.

Given the rapid ascendancy of ESA, this is a particularly bad time to jeopardize a long-standing and, to date, well-working partnership through lack of consultation.

We must find ways of consulting with our partners abroad more equitably. Space ventures are so expensive that we must not unnecessarily alienate cost-sharing partners, especially at a time when Congress no longer has the means to adequately fund even the most important missions on NASA's agenda.

When Congress canceled the Superconducting Supercollider this year, the lead in fundamental particle physics, once the unchallenged domain of American physicists and source of many Nobel prizes, crossed over to Europe. The huge accelerator installations in Geneva will now dominate this field. American physicists wanting to stay active in this area of research will have to travel to Switzerland.

Given current financial straits, a similar curtailing of U.S. space efforts is not inconceivable. And close relations with partners abroad could then be essential to help us conduct programs that otherwise would have to be dropped.

—Martin Harwit is the director of the National Air and Space Museum.

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LETTERS

Comic Comments

I too grew up with Terry and the Pirates ("Combat Comics," December 1993/January 1994). And I also had a number of scrapbooks that my mother disposed of in one of her moods.

Milton Caniff did one of the most sensitive pictures of my father, and another for the Air Force Association when it gave Dad an award. Caniff also drew a small picture of Steve Canyon for me, which I treasure.

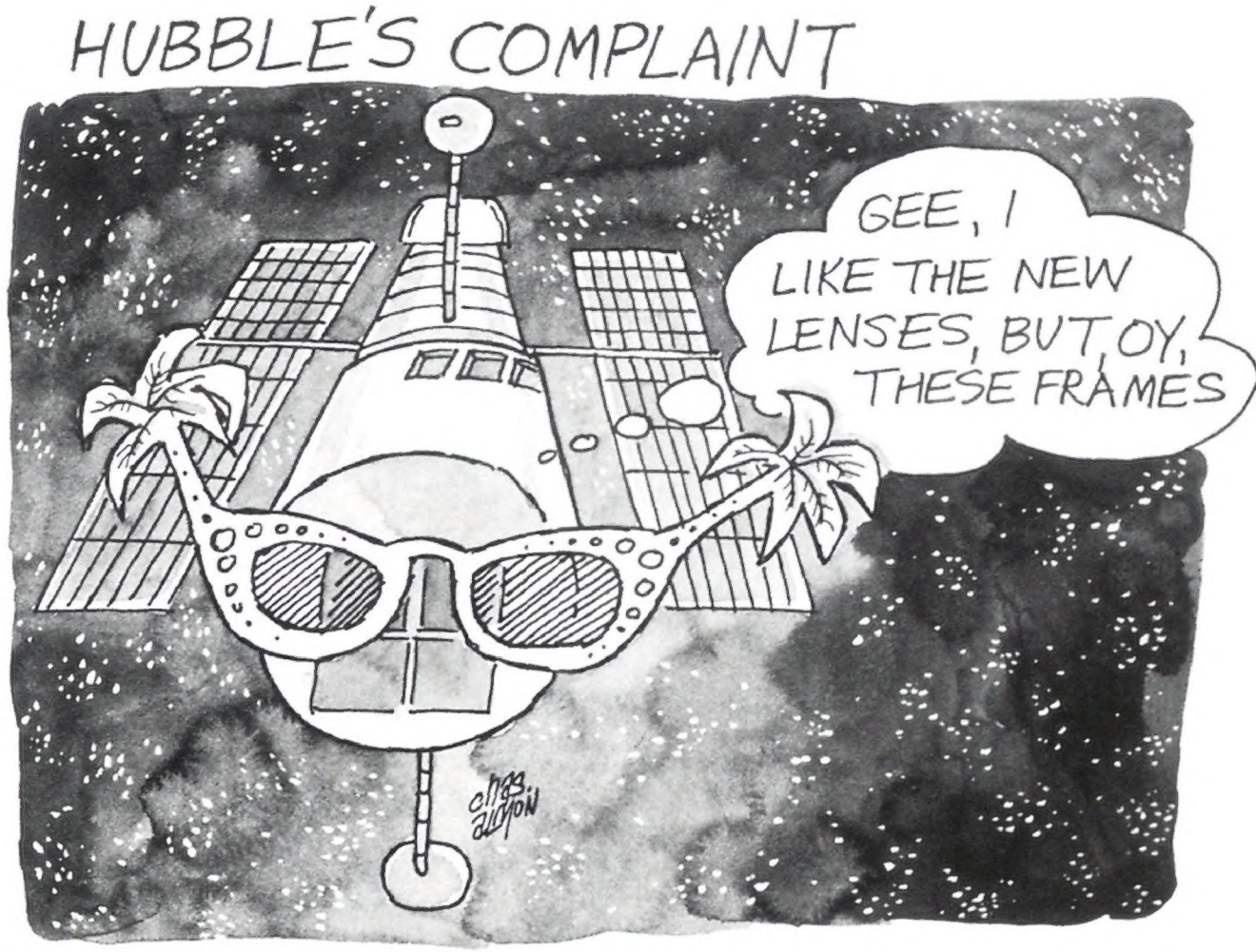
When Caniff wanted to draw an R-4 helicopter for the Terry strip, he wrote Dad's office and got a number of photographs. Typical of him to do his homework.

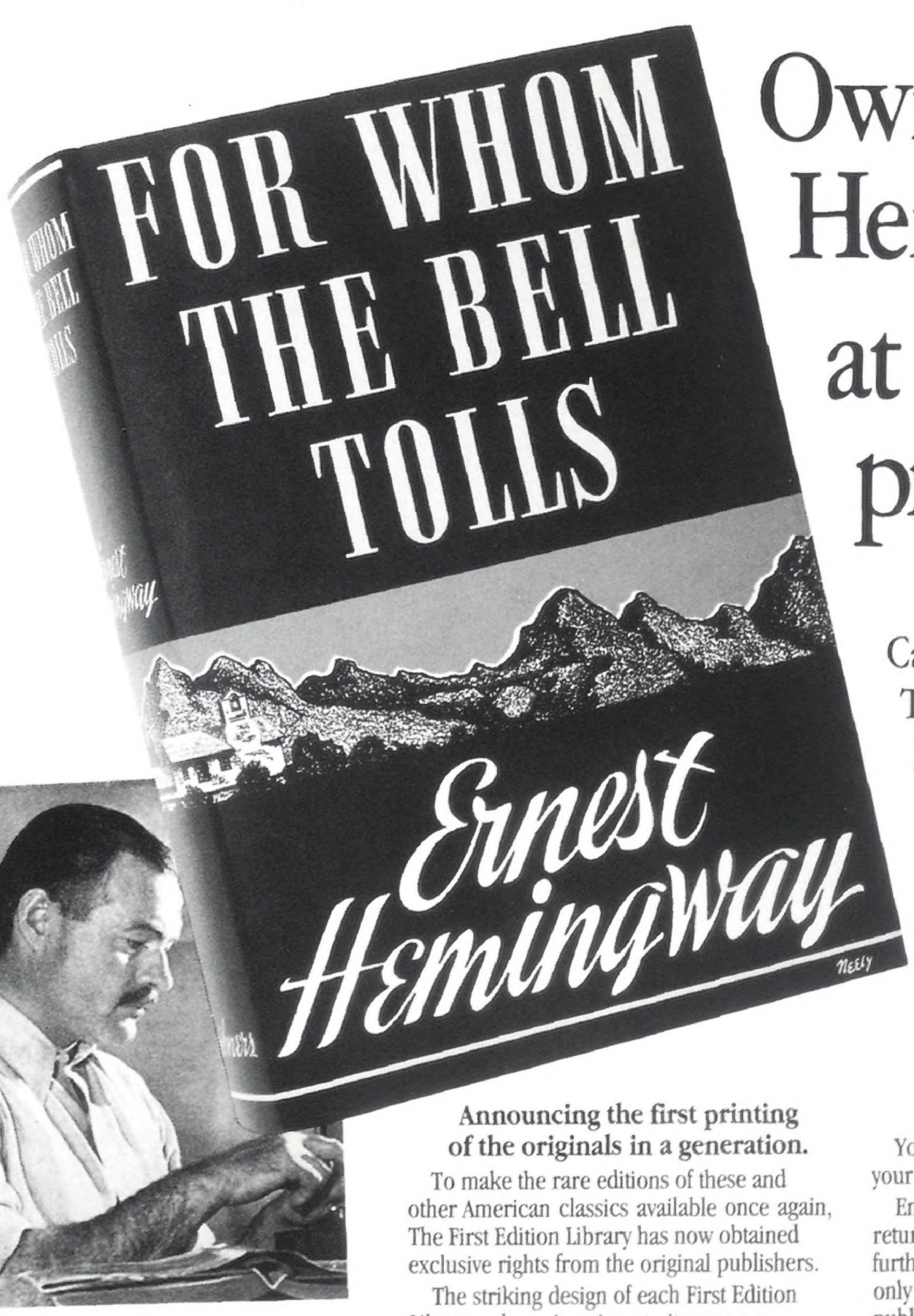
—Igor I. Sikorsky Jr.
Rocky Hill, Connecticut

"Combat Comics" states that "Barney Baxter's Devil Cat fighter-bomber was wholly the creation of artist Frank Miller. It had no real-life counterpart." However, seven years prior to Barney's raid on Tokyo, an almost identical airplane, the Gyro Crusader, was flying over Colorado. Only in the front canopy and the length of the nacelles did the Devil Cat and the Crusader differ.

The Crusader made its maiden flight on January 6, 1935, taking off from Denver Municipal Airport. (The pilot was Ray Wilson, who later founded Frontier Airlines.) Only one Crusader was ever made, but it was an instant success: it flew demonstration flights over much of the country, was exhibited widely, and served as a model for toy copies, which are much sought after today. The Crusader was eventually destroyed in a fire.

In 1970, the Crusader's designer, Thomas Shelton, was inducted into the Colorado Aviation Hall of Fame, principally on the basis of this aircraft.





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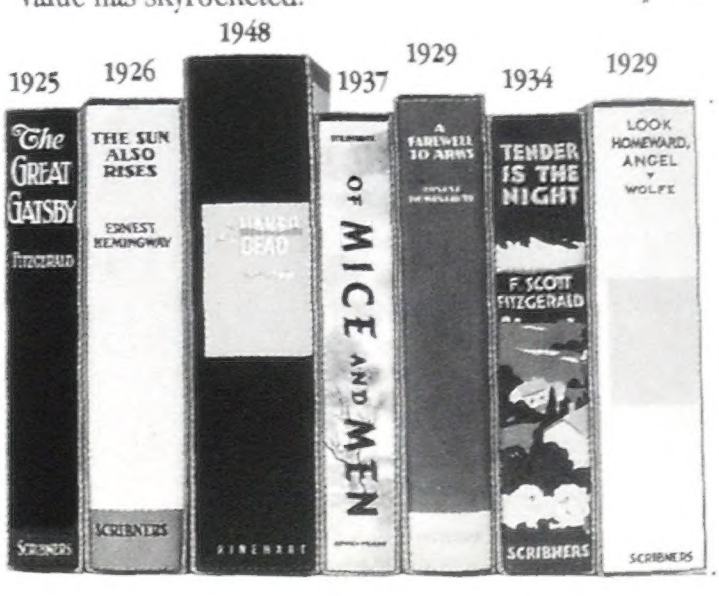

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LETTERS

I commend Frank Miller on his taste in aircraft, but not his originality.

—Charles W. Holmes
Director,
Colorado Aviation Historical Society
Greeley, Colorado

Hal Higdon made reference to a character in Smilin' Jack who has stuck in my mind for 50 years. Isn't it true that the most one ever saw of Downwind was the back of his head, ear, and cheekbone?

—Marc Feldman
Berkeley, California

Editors' reply: You're right. According to The Encyclopedia of American Comics: From 1897 to the Present *(edited by Ron Goulart), Downwind Jaxon had a face "so handsome that we were never permitted to see more than a one-quarter profile."*

"Combat Comics" struck a harmonic chord. I too devoured all the comic strips and books relating to the war in the air. And my collection suffered much the same fate as Mr. Higdon's: while I was in the Navy my parents shipped all my comics to a paper drive, including two treasured dailies I got from Frank Robbins, the creator of Johnny Hazard.

My contribution to the war effort was carving out scale models of military aircraft, painting them black, and sending them off to serve as recognition models. Robbins had created a Japanese Corsair lookalike in his strip. I carved out a copy and sent it to him as a Christmas present. He sent an original drawing with a thank you note, as well as the dailies.

Let me add that while Terry and the Pirates is one of my top three favorites, I must take exception to Mr. Higdon's remark that Milt Caniff "shamed artists like Robbins and Crane" in his portrayal of people. Some of his characters, especially the villains, were better suited to Dick Tracy.

—Lorin L. Wilkinson
Capt., Western Air Lines (ret.)
Yelm, Washington

A Closer Look

"Securing the High Ground" (December 1993/January 1994) states that the picture

"You have reached Bayview Airport. For general information, press 1. For service, press 2. For our fax number, press 3. For the business office, press 4...."

on page 64 shows President Kennedy visiting the Army's ballistic missile agency in Alabama. Actually, the picture was taken at Cape Canaveral in Florida, during Kennedy's only visit there. The picture also makes clear that he was briefed by the Air Force, not the Army: the officers are wearing Air Force uniforms, and the models on display are Air Force vehicles. In addition, Kurt Debus is visible two heads to the right of Kennedy. Debus was an associate of Wernher von Braun's who wound up at the Cape in the mid-1950s. He went on to head the Kennedy Space Center during the Apollo program, the development of the Saturn IB and V, and more.

—Jerry Weinstein
Herndon, Virginia

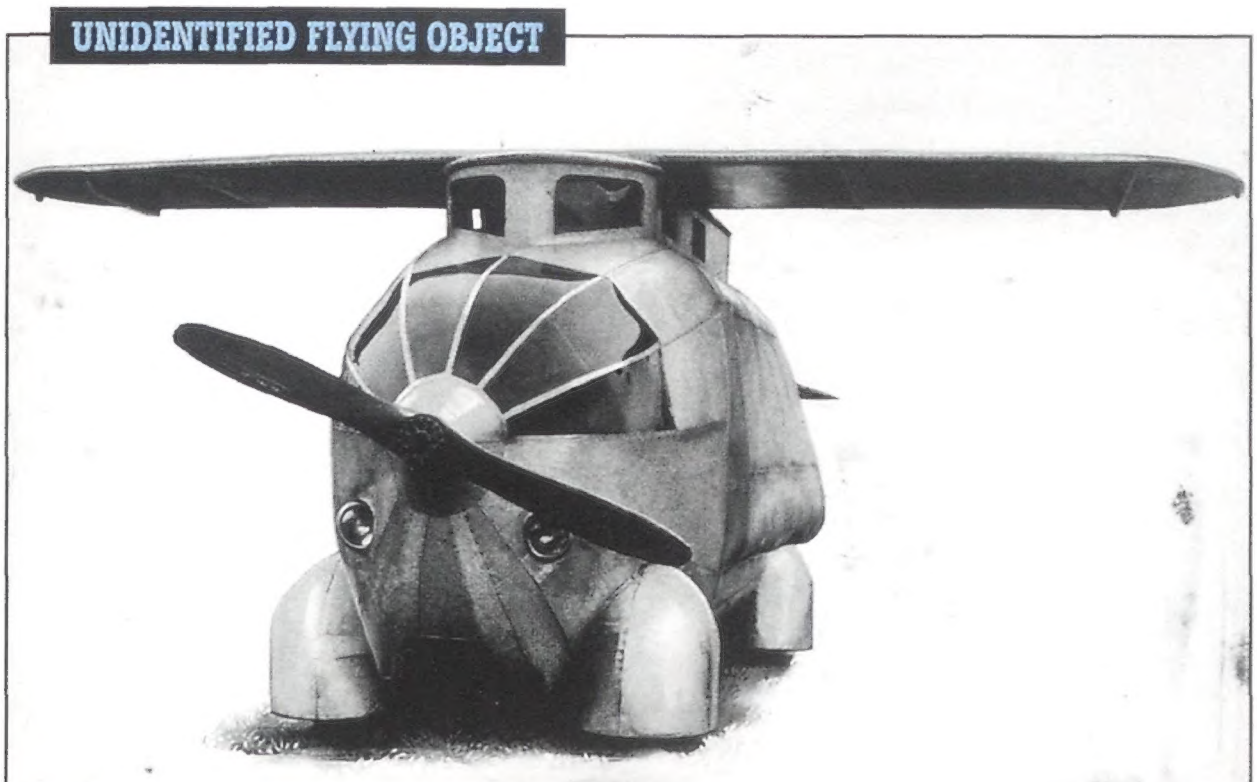
In "Securing the High Ground" I noted that in the picture of the space shuttle on page 69, six Rockwell employees were leaning on handrails and one was leaning against a table, arms folded. I hope that the relaxed postures of these employees are not indicative of the everyday business at this plant. Those employees would certainly make better use of our tax dollars by doing something more productive than honing their railbird skills, and NASA would probably prefer to project a better public image as well.

—Guy Singleton
San Juan Bautista, California

Hope for the Best, Expect the Worst

In "Reality Check" (October/November 1993) Ron Farris and Story Musgrave make valid points about the training lessons learned from the botched Intelsat rescue attempts. But they ignored the single biggest mistake committed on mission STS-49: when the infamous capture bar didn't snare properly and the satellite tumbled away, the *Endeavour* crew had no alternative means of

UNIDENTIFIED FLYING OBJECT



Can you identify the aircraft in this photograph? From time to time the National Air and Space Museum receives photographs of objects that its archivists cannot identify. In the case of this very odd-looking vehicle, the archivists do *know what to call it but don't have a clue as to how it was supposed to be used. Called the Mono-Dirigible, it was constructed in France for an American aviator named Frank Bolger. It has propellers mounted at the front and the rear and was purported to be an all-metal design. The photograph is dated 25 June 1932. If you can solve the mystery, write to:* Letters, Air & Space/Smithsonian, *370 L'Enfant Promenade SW, 10th Floor, Washington, DC 20024. Please type or print clearly, and include your daytime phone number.*

Last issue's UFO has yet to be identified. It is not, as some readers suggested, a Republic Seabee.

grabbing the satellite. Given the number of past satellite capture attempts that ended up requiring manhandling and jury-rigging, it's particularly astounding that STS-49 had no alternatives to call on.

More accurate simulation is only part of the solution. Formulating a backup plan is absolutely essential for successfully planning and executing missions in the unforgiving environment of space.

—Robert J. Mahoney
League City, Texas

The Unawarded Airman

I thought your readers might be interested to know more of the story Norman Isler recounted in "The Unknown Airman" (Above & Beyond, October/November 1993).

Because he was wounded during that July 7, 1944 mission, my father, Edward M. Lindbloom, received the Purple Heart, but he did not receive a decoration for his military service; the recommendation for that award was lost. However, thanks to Norman Isler's research and the extraordinary efforts of U.S. Representative Bob Smith of Oregon, Air Force major Edward M. Lindbloom (ret.) was finally awarded the Distinguished Flying Cross on November 11, 1993—nearly 50 years after his last mission.

—Ken Lindbloom
Medford, Oregon

Gloria's Distinguished Friends

I was quite interested in your article "Posthaste" (Oldies & Oddities, December 1993/January 1994). For one thing, I have one of the envelopes that was on Frido Kessler's rocket plane (I had addressed it to myself). In addition, several dignitaries were associated with those demonstration flights. For instance, before the flights, experiments to test the undertaking were carried out near Roswell, New Mexico; the man who conducted them was Robert Goddard. And Willy Ley, who you mentioned had applied the torch that ignited the Glorias, was at the time president of the German Rocket Society. His counterpart, G. Edward Pendray, president of the American Rocket Society, also showed up, though he apparently regretted doing so; at the time, he was heard to exclaim: "This performance is damned embarrassing to us serious experimenters!"

—Walter Bastedo Jr.
Hendersonville, North Carolina

"Do you know 'The Wind Beneath My Wings?' "

"Can we use your phone?"

Who Designed the X-1? (continued)

I must take issue with Dexter Rosen on the role Robert J. Woods played in the design of the X-1 (Letters, December 1993/January 1994). At the time Bell received the go-ahead to design an airplane powered by the RMI rocket engine, I was a design engineer in Bell's aerodynamics department. I was assigned to work with Benson Hamlin in a small office furnished with one desk and one drafting board. Woods worked closely with us during the entire preliminary design phase. Hamlin did the theoretical work while I made all the design layout drawings, as well as the three-view general arrangement drawing. This defined the overall geometry and placement of all major components and was in basic agreement with Woods' design concept sketches.

Upon completion of the preliminary design phase, Woods proceeded to other projects but continued to give his input to the production design team.

—Leslie V. Beukema
Wilson, New York

A Lone Survivor

In "Flier's Market" (October/November 1993), Julius Maldutis of the Salomon Brothers brokerage firm says that not one carrier that was started in the 1980s has survived. In fact, Phoenix-based America West Airlines was started in the '80s and is now the ninth largest U.S. carrier.

—Jeffrey B. Welty
Portland, Oregon

Correction

December 1993/January 1994 Letters (Corrections section): The illustration for "Training Flight" (Above & Beyond, June/July 1993) did in fact correctly depict the PB4Y-1, the aircraft referred to in the article. It was a later design, the PB4Y-2, that had a single fin and rudder and was known as the Privateer.

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Cosmic Collectibles, Cosmic Prices

SOTHEBY'S (2)

Sotheby's, the renowned purveyor of top-shelf collectibles, is used to handling antiquities from around the world. But the scene last December at its New York offices astonished both the staff and its clients as the firm auctioned off 226 lots of Soviet space history. Documents and hardware from a program that had been cloaked in secrecy for decades were not only open to view but up for grabs.

Rare-manuscript specialist David Redden, who conceived the auction three years ago, knew he had a good thing going by the 15th lot, when a brief post-flight report signed by cosmonaut Yuri Gagarin was sold to an anonymous bidder for $354,500. But even Redden was amazed by the response from the nearly 400 space aficionados who registered to bid on everything from signed photos to space capsules.

This sale was not for the fiscally faint of heart. A slide rule once used by spacecraft designer Sergei Korolev, the program's mastermind during the 1950s and '60s, brought more than $24,000. A fully outfitted cosmonaut mannequin named Ivan Ivanovich, flown in 1961, brought a winning bid of $189,500. Gherman Titov's fork went for $6,900, and training suits for backup cosmonauts could be had for a mere $3,500. But the one Aleksei Leonov trained in prior to his 1965 spacewalk commanded $225,500—also what the Tokyo Broadcasting Company paid for the suit worn by one of its reporters, Toyohiro Akiyama, on a 1990 flight to the Mir space station. Three tiny rock chips returned in 1970 by Luna 16 went for $442,500—the first public sale of lunar material.

Sometimes prices weren't the only thing out of bidders' reaches. A cosmonaut's guitar, which sold for $13,800, is still aboard Mir and likely won't get to its new owner until this summer. And for a mere $69,000 some lucky individual bought the title to the Lunakhod 2 lunar rover, which continues to gather cosmic dust about a quarter-million miles away, in eastern Mare Serenitatis (Sotheby's does not guarantee future title).

The highest high roller was an American who shelled out nearly $3 million for two space capsules, Gagarin's three-page report, and other major items. The anonymous buyer, who modestly calls himself a "temporary custodian," hopes to place the artifacts in museums and eventually return them to the Russian government.

"This was an absolute dream come true," said the exhausted Redden, who with collaborator Peter Batkin egged on bidders for six hours. However, established brokers in the burgeoning space memorabilia trade were stunned by the sums being paid. Dealer Leo Malz, outgunned on almost every offering, could only shake his head in disbelief, opining that the buyers seemed willing to pay anything "just because it's Sotheby's."

—J. Kelly Beatty

Name Dropping

A group of U.S. space station devotees were thrown into a quandary last autumn when NASA administrator Dan Goldin decreed that the proposed orbiting outpost should have a new name to herald its new identity as a joint venture with Russia.

Because the old name, Freedom, wasn't one of the five finalists NASA was considering late last year, the Freedom Fighters of Houston, Texas, were having their own identity crisis.

"The station is being temporarily called the Alpha Station, but we don't want to be called the Alpha Bits," says Cynthia Griffin, the leader of a nationwide drive to document public support for a space station—any space station—with a million signatures. In the last two years the Freedom Fighters have collected 37,000 signatures.

NASA didn't invite the public to submit names, as it did with the *Enterprise*, its shuttle test bed, but Griffin's group collected suggestions at airshows and conventions and passed along to Goldin 16 names, as well as an impassioned plea to leave well enough alone. "With the fall of communism in the former Soviet Union

and the demise of the Cold War many more people of the Earth are experiencing Freedom for the first time, making the concept of 'Freedom circling the Earth' closer to reality," Griffin wrote the administrator. Besides, she added, keeping a name that is recognized by the original international partners "and by the public, the true owners of the space station...will also save the costs of changing the station's name."

Freedom accounted for 62 percent of the recommendations the group received, Griffin says. Also on the repeat list were Hercules, Independence, Landmark, Liberty, Pegasus, Starlight, and Unity. Other suggestions were Patriot, the name of a U.S. missile, and Peacemaker; 42 (the answer to everything in Douglas Adams' book *The Hitchhiker's Guide to the Galaxy*); and Jennifer [*sic*] Flowers. Griffin cites that one as "an embarrassment to us," but she submitted it nonetheless, as was promised to all suggestees. "We even had an ELVIS—it meant Extra-Lunar Vehicular International Station or something like that," she says.

Goldin was expected to ask President Bill Clinton to make the final choice from a secret A-list that may have included the names Unity, Alliance, Aurora, Alpha, and Sigma. "I personally find Aurora to be the most intriguing," says Griffin. "Aurora is the goddess of the dawn and would make the space station the largest NASA project to have a feminine name." But the name Aurora has long been attached to a high-speed spy plane supposedly under development by the Pentagon. "I'm not sure how our new space station partners, the Russians, will take to that name," Griffin says.

Jeff Vincent, NASA's associate administrator for public affairs, refuses to reveal the names he sent to Goldin. "If anybody's uptight about it, it's the news media," he says. "We're going to name the space station and we'll name it when we're good and ready."

—Beth Dickey

UPDATE

Barber Battles On

Rex Barber has lost yet another bid to claim full credit for shooting down the bomber carrying Japan's naval commander in 1943 ("Who Shot Down Admiral Yamamoto?," February/March 1992). Last November a federal judge in Oregon refused Barber's request to force the military records board to reconsider its decision to give Thomas Lanphier half the credit.

11,500 Miles by Biplane

In November 1919, Australians Ross and Keith Smith and a crew of two took off from England, bound for home in a surplus Vickers Vimy biplane bomber. Emblazoned on its fuselage were the registration letters G-EAOU, which the crew, aware of the perils of the 11,500-mile journey, said stood for God 'Elp All Of Us. Similar fears must have plagued Britain's John Alcock and Arthur Brown when they made the first nonstop transatlantic flight five months earlier, also in a Vimy.

This year marks the 75th anniversary of the two flights, and both will be re-created by "Vimy 19/94," a project conceived by Lang Kidby of Brisbane and his U.S. copilot and partner, Peter McMillan.

Lang Kidby will pilot a replica of a 1919 twin-engine Vimy from England to Australia this September and fly the Atlantic in 1995.

In September, as a highlight of Britain's Farnborough airshow, the pair will take off on the England-Australia flight in a replica of a twin-engine Vimy. "I am sure that we'll not get far before we are asking ourselves what on earth we are doing there," says Kidby, a former Australian Army Aviation pilot who in 1990 organized and participated in the World Vintage Air Rally, in which 24 antique aircraft flew from London to Brisbane. Early in 1995, Kidby and McMillan will tackle the Atlantic.

In June 1919, Alcock and Brown took off from Newfoundland and crashed in an Irish peat bog. At one point, to prevent the airplane from coming down in the Atlantic, Alcock fought to keep the Vimy level while Brown climbed out on the wing to chip ice off the engines.

During the Australians' 27-day flight, the crew faced the heat and dust of the Middle East, monsoons over Asia, and a frigid European winter. Over France, their goggles were coated with snow and ice. Even the sandwiches froze. Ross Smith wrote, "This sort of flying is rotten. The cold is hell. I am a silly ass for ever embarking on the flight."

McMillan, a San Francisco stockbroker who put up $250,000 to get aircraft construction under way, emphasizes that this is serious business, not a publicity stunt. The replica is equipped with an elevator trim system (the original had none) and a global positioning system receiver for navigation. During the Atlantic crossing the Vimy will be escorted by a Grumman Albatross flying boat. The biplane is powered by a pair of Chevrolet V-8 engines with huge four-blade wooden propellers. The engines, rebuilt and beefed up in Australia, provide 900 horsepower, 180 more than the original Vimy's Rolls Royce Eagles produced.

The replica was assembled in the woodworking shop of an old film studio near San Francisco. Australian aeronautical engineer Bill Whitney had produced thousands of working drawings from a set of original Vimy plans. He says it was simpler than his previous project—building a flying replica of Sir Charles Kingsford Smith's Fokker *Southern Cross*.

In 1919 the Australian government awarded the Smith crew a $20,000 prize, and Britain's *Daily Mail* newspaper awarded a similar amount for the Atlantic flight. Handing Alcock and Brown their check, Winston Churchill, then Secretary for War, said, "I don't really know what we should admire most: their audacity, their determination, their skill, or their good fortune."

—Terry Gwynn-Jones

Solar-Powered Spy

Residents of California's Mojave Desert are used to the exotic shapes, screaming engines, and sonic booms coming out of NASA's flight research center at Edwards

Air Force Base. But Edwards' latest craft is a lumbering flying wing called Pathfinder that can be outrun by a half-decent bicyclist. Designed by Paul MacCready, a pioneer in lightweight craft, and his crew at AeroVironment, Inc., Pathfinder is the prototype of a reconnaissance and defense system sponsored by the Ballistic Missile Defense Organization (formerly the Strategic Defense Initiative Organization).

The 98-foot wing weighs a mere 430 pounds and glides at 20 mph. It is powered by eight electrically driven propellers. One-third of its skin is covered with solar cells that augment onboard batteries and should give Pathfinder a range of some 100 miles. Pathfinder's successor might carry sensors to detect ballistic missiles and be outfitted with missiles of its own to intercept them.

Conceived and built secretly in 1983, Pathfinder was flown several times before being shelved because its electrical system was too heavy to permit nonstop flight. But advances in the development of compact, rechargeable fuel cells, which draw power from the interaction of hydrogen and oxygen, have given the program a second chance. Once Pathfinder has proved flightworthy, a 200-foot model called Sunflower will be tested in the calm air at 65,000 feet and flown continuously in daylight. In the meantime, the top of Pathfinder's wing will soon be completely outfitted with solar cells for a summer-long test flight above the Arctic, where an onboard instrument will make ozone measurements.

While acknowledging Pathfinder's military roots, MacCready has other applications in mind. How about a relay antenna 10 miles up that can be positioned anywhere you want? MacCready says that option causes "mouths [to] water when they hear about this" in the telecommunications field.

—J. Kelly Beatty

CHAD SLATTERY

Last December, 16 retired Douglas Aircraft Company employees gathered in Long Beach, California, for a flight on a DC-2, an airplane they had designed 60 years ago. Collectively, they represented 500 years of service to Douglas. "That's half a millennium," says Bill Losch, who organized the flight. "They were the best years of our lives, working for a great firm. The DC-2 set in motion the airliner industry as we know it today." The DC-2, restored by the Douglas Historical Foundation, is one of only two in existence today. It was delivered to Pan Am in March 1935 with a burgundy and gray interior.

On the way home the starboard engine magneto acted up and the crew decided to shut down the engine. The unruffled passengers, who knew the airplane could fly over the Rockies on a single engine, just kept reminiscing. "We're all hot-air artists," says Losch. "We could keep it aloft if both engines quit."

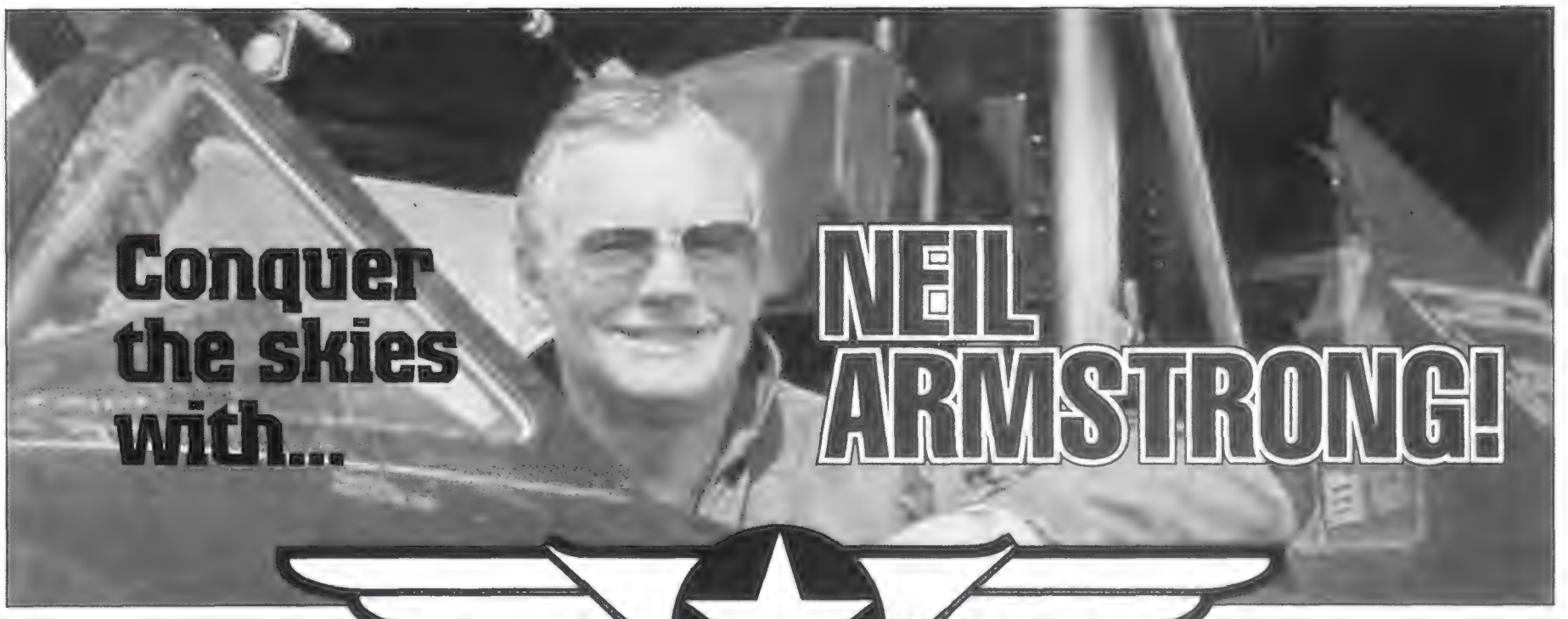
Gone but Not Forgotten

At Mary Nina Hart's place you can buy chocolates, frozen yogurt, jelly beans, or Pan Am memorabilia. If you choose the latter, you'll help support a campaign to create a Pan American Airways museum.

Hart runs PanAware, which opened last July in the Barricini's Candy Store opposite Tracks 18/19 in New York City's Grand Central Station. Sharing a crowded wall with boxes of chocolates are Pan Am T-shirts, tiny Pan Am airliners, commemorative plates, a teddy bear in a Pan Am shirt, plastic coin purses in the company colors, and a bumper sticker that reads "Pan Am: Gone but Not Forgotten."

Hart is a volunteer, and the money PanAware takes in supports the Pan Am Historical Foundation's efforts to build a museum in Miami. (Another PanAware store is located in the old Pan Am International Flight Academy at Miami Airport.) According to Paul Roitsch, a former Pan Am captain and now a member of the foundation's board of directors, the organization wants to build the museum on Biscayne Bay's Dinner Key, site of the original terminal for the flying boats Pan Am operated out of Miami. "The Miami City Council has twice passed resolutions proclaiming their desire to see this building, which is

NASA



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currently the Miami City Hall, become an aviation museum," says Roitsch, but he adds that presently the foundation lacks the funds to buy the building from the city. "We may have to seek alternate arrangements," he says.

Roitsch says there are over seven tons of Pan Am documents and 10,000 photos and negatives at the University of Miami's Richter Library to fill the proposed museum. "That is the world's largest collection of material devoted to a single airline," he says proudly.

The New York store is just steps away from the office tower once owned by Pan Am, back when the Pan Am name and blue logo were part of the Manhattan skyline. The building now bears the name of a life insurance company, but most New Yorkers still refer to it as the Pan Am building. The logo was saved for future display, but of the letters that accompanied it, only the "P" was salvageable.

Hart, who retired in 1980 after 29 years in Pan Am's tour department, says that in the store's eight months of existence it has become a focal point for ex-Pan Am employees. They still hold meetings in Tokyo, Frankfurt, and "wherever there was a Pan Am presence." The airline instilled a unique sense of loyalty and family, she says, adding that Edward Trippe, son of Pan Am founder Juan Trippe, shows up twice a week to work the counter.

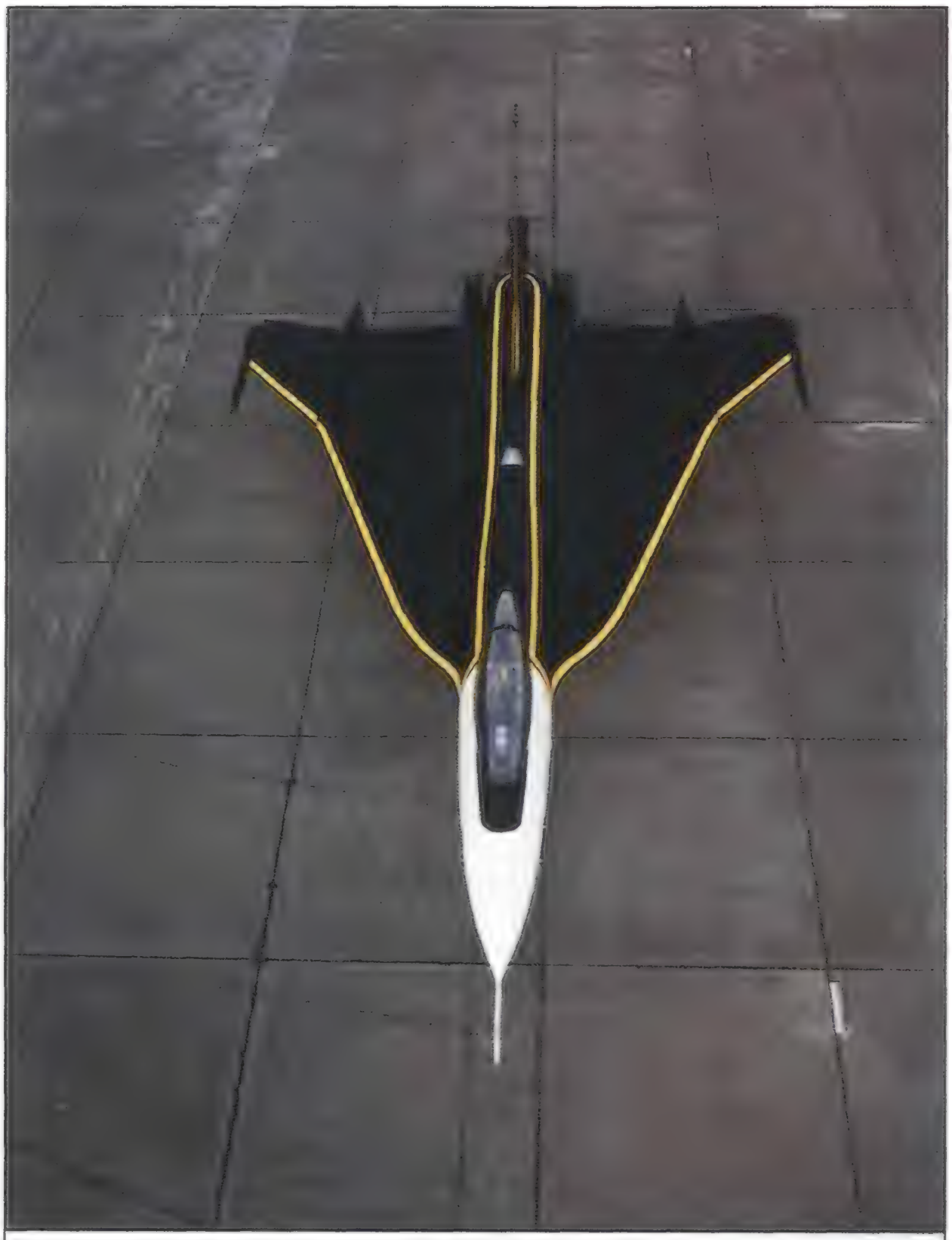
—Stan Solomon

UPDATE

Departures

Cole Palen, who founded the world-famous Old Rhinebeck Aerodrome in upstate New York where antique and replica aircraft were flown in weekly shows ("Wings of the Great War," October/November 1991), died last December 8 in Florida at age 67. He had suffered a stroke earlier in the year. "His whole life was aviation," said long-time colleague and Old Rhinebeck pilot Richard King. "He lived and breathed it."

Zack Mosley, creator of the Smilin' Jack comic strip ("Combat Comics," December 1993/January 1994), died last December 21 in Stuart, Florida, after a heart attack. He was 87.



NASA LANGLEY

Topping aviation's Best Dressed list is NASA-Langley's F-16XL, outfitted in midnight black and accessorized with gold, with a NASA designer label (accept no off-the-rack substitutes). The paint scheme provides the contrast necessary for the study of aerodynamic flow. The F-16XL is undertaking studies for the High Lift project, part of NASA's High Speed Civil Transport program.

A Cadet Who Counted

Sidney J. Brooks Jr. never chased German pilots through the French skies; in fact, he never flew his Curtiss JN-4A beyond Texas hill country. But on a blustery Veterans Day afternoon last fall in a ceremony at the Air Force base that bears his name, officers and historians described the World War I cadet as a trailblazer who helped make flight safer.

"He was one of a small band of pioneers who gave us the Air Force we have today," said Air Force historian Richard Hallion. "Brooks demonstrated the qualities that make a good aviator. He had a sense of adventure without a foolish sense of risk-taking."

But Brooks died during his final training mission on November 13, 1917, at age 22, because aviation was a risky business. As he descended toward San Antonio's Kelly Field Number 2, his aircraft pitched forward and plunged 50 feet to the ground. At the time, fellow pilots speculated that Brooks, fatigued from a lengthy physical exam and feverish from a series of immunizations received that morning, fainted and fell on the control stick.

At the time, neither pilots nor physicians understood how the human

DAMOND BENNINGFIELD

body reacted to the rigors of open-cockpit flight—the constant vibration, the acceleration, the vapors from hot engines. The death of Brooks and many other young pilots forced the military to investigate the physiological effects of flight. Today the effort continues at the School of Aerospace Medicine at San Antonio's Brooks Air Force Base, which the War Department named for the cadet weeks after his death.

Last November Brooks' remains were reinterred at the base that bears his name. His original burial site, San Antonio's Alamo Masonic Cemetery, had fallen into disrepair. Its fence was gone, and vandals had defaced and destroyed many of the headstones.

A military honor guard escorted the coffin, draped in an 1895 flag, which completed the journey in a World War II military ambulance after the World War I ambulance broke down. Brooks was buried with his pilot's wings, awarded posthumously, at the base of a granite memorial topped with a bronze eagle. Now his remains rest just a few miles from the crash site.

—Damond Benningfield

Shoemaker's Rocky Road

The guest list was a Who's Who of planetary exploration. At one table sat Harrison Schmitt, the only scientist to walk on the moon. Next to him were geologists Leon Silver and Gordon Swann, who helped prepare Schmitt and his astronaut colleagues for their explorations. Around the banquet room were scientists who had participated in the Voyager missions to the outer planets. All had come to Flagstaff, Arizona, last October to celebrate the career of

USGS

Eugene Shoemaker (left) and Harrison Schmitt reminisced about Apollo in Flagstaff last fall.

geologist and astronomer Eugene Shoemaker, whose curriculum vitae was handed out to guests in the form of a geological cross-section, with rock layers representing years.

In 1960, at age 32, Shoemaker made the first comprehensive geological study of Arizona's Meteor Crater, proving that it had indeed been formed by meteoric impact. That study laid the groundwork for Shoemaker to create, almost singlehandedly, the discipline of lunar geology. All the while, his personal goal was to become the first scientist on the moon. Henry Moore of the United States Geological Survey recalled that in the 1950s Shoemaker would tell him, "Someday we're going to the moon." This prompted another disbelieving colleague to say, "Shoemaker wants to go to the moon, and I want to light the rocket that will send him."

But in 1963, as NASA was drawing up plans for manned lunar missions, Shoemaker's goal was shattered by Addison's disease, an adrenal gland disorder. Meanwhile, in Flagstaff, he created the astrogeology branch of the USGS and focused his efforts on getting NASA to enlist scientist-astronauts for the lunar missions. The list of selectees included one of his staff geologists, Harrison Schmitt.

On the last Apollo mission, in December 1972, Schmitt got to carry out the explorations Shoemaker had longed to make. "I know you wish you could have done that study yourself," Schmitt told Shoemaker and guests at the banquet, "but I only hope that those of us who acted in your stead got at least part of the job done."

After Apollo, Shoemaker extended his expertise to more distant bodies,

analyzing the Voyager images of the icy moons that orbit the outer planets. He also took to the telescope, searching for uncharted comets and asteroids. Today that pursuit is luring Shoemaker from the USGS to nearby Lowell Observatory, where he will conduct more detailed surveys.

In a "This Is Your Life" review, guests spoke of Shoemaker's vitality and the boost he gave to colleagues. "That's why we figured out the geology of the moon," geologist Don Wilhelms later explained. In the early 1960s, Wilhelms had been one of a number of scientists who extended Shoemaker's efforts, making the first detailed lunar geological maps (see "A Smooth Spot in Tranquility," June/July 1989).

One of the most compelling portraits was offered by USGS photographer Hal Stephens, who in the 1960s accompanied Shoemaker on a three-month trip down the Colorado River retracing the 19th century geological expedition of John Wesley Powell. Stephens described how Shoemaker, lying in his sleeping bag in the morning stillness, would prop himself up on an elbow and plan the day's activities. From such musings, no doubt, sprang the dream of exploring other worlds.

—Andrew Chaikin

UPDATE

New Airline News

A running scorecard on the frenzied activity in the startup airline industry ("Flier's Market," October/November 1993):

Southwest Airlines announced last December that it would purchase Morris Air, based in Salt Lake City.

A Department of Transportation administrative law judge recommended to transportation secretary Federico Peña last December that because companies owned by Frank Lorenzo had sometimes acted "past the bounds of legal conduct," Lorenzo be denied reentry to the airline business.

UltrAir, minus Barney Kogen, underwent a makeover and last November started providing low-cost, no-frills service from New York's Kennedy airport to Florida.

The Great Paper Airplane Contest

RICHARD NOWITZ

It was a blustery Sunday afternoon in November, a perfect day to spend wandering through a museum. If you're an adult, that is. If you're a kid, well...

The National Air and Space Museum understands that even the coolest rockets and fighter planes can hold a young visitor's attention for only so long. To give the kids a chance to cut loose a little, the educational services department has worked up a half-hour's diversion—the Great Paper Airplane Contest, held every Saturday and Sunday at 2:30 p.m. in the Pioneers of Flight gallery.

One recent afternoon, intern Helen Ding, a brisk, good-natured Johns Hopkins student, got the day's contest under way. "Now for this contest there are three trials," she explained to the 20 or so kids sitting cross-legged on the floor. "The first two trials are practice—they don't count. The last trial does count. If you're the winner of the last trial you get a prize." She threaded her way among the contestants, passing out sheets of lined paper. "All you do is fold back on the lines," Ding explained. After a few minutes, the kids had fashioned more or less identical versions of the classic teacher-harassing dart design.

"Okay, I think everyone has the basic design of an airplane," Ding said. "Since we're in the *National* Air and Space Museum, we're going to be a little more sophisticated. We'll teach you a little bit about aerodynamics so that the plane is going to fly straight." To demonstrate the concept of stability, Ding showed how a wood rod is stable when held from the top and unstable when held from the bottom. She also pointed out that nowadays, some aircraft are actually made to be unstable. "Let's say you wanted to be doing a lot of turns easily, you wanted to maneuver easily—those planes are unstable," she said. "They are so unstable that a human brain cannot control them, so we have computers to fly those airplanes." Then, in the old tradition of wacky teachers livening up lectures with wacky props, Ding proceeded to demonstrate the inadequacy of the human mind by pulling out a giant Mason jar with a pale gray brain floating inside. "I know some people think this is clay," she said, "but this is an actual human brain. If you're interested, come up and take a closer look at the end of the show." Three boys immediately crowded around the jar.

Ding explained that the contestants would use paperclips to produce different centers of gravity for their airplanes. For the first trial they fastened clips onto the ends of the airplanes' fuselages. When they were ready, Ding had them line up about six feet from a small cart on top of which stood a metal hoop. One after the other the children threw their planes at the hoop, and one after the other, the planes curlicued back at them.

"With a very few exceptions, everyone had very unstable airplanes," said Ding. She then instructed the children to fasten the paperclips at the front of their aircraft. "Now I want you to look at the planes around here," she said, pointing to the Vin Fiz and Amelia Earhart's Lockheed Vega. "These planes all have the center of gravity in the front. What do they have in the back? In the back they have tails." Ding showed the children how to make upward tail curves that would catch the air and keep their nose-heavy planes from crashing. When the kids were ready, they lined up once more. This time, most of the entries sailed right through the hoop.

Now, with confidence high and drag low, the contestants were ready for the main event. Each child stepped up to the line. Some squinted, some held their breath, some leaned, some hunched. The onlookers—mostly parents—provided the *oooooh*s and *awwww*s. But all in all it was a relaxed affair, and none of the kids who missed the hoop looked terribly put out. By the end it was down to two boys, poised about eight feet from the hoop.

But children's attention spans have their own short trajectory. By the time a cheerful-looking boy named Ben had won the grand prize of an X-29 button, most of the other kids were starting to wander out of the gallery.

Except for a few who were gathered around the brain.

—Perry Turner

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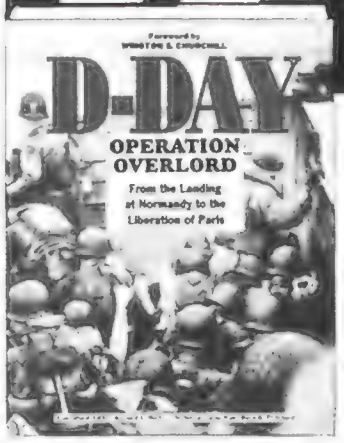

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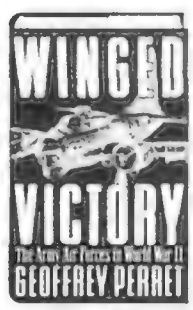

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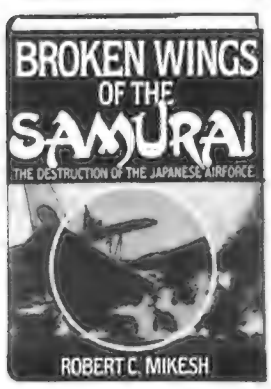

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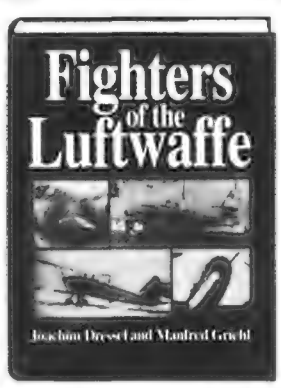

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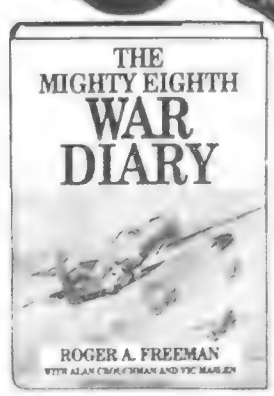

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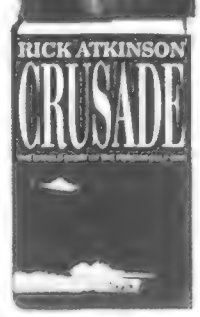

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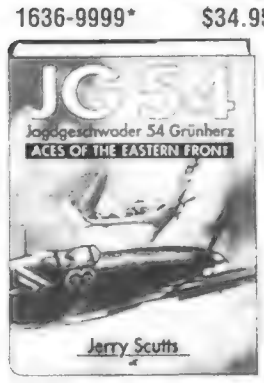

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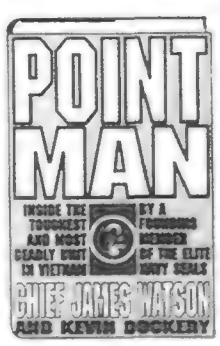

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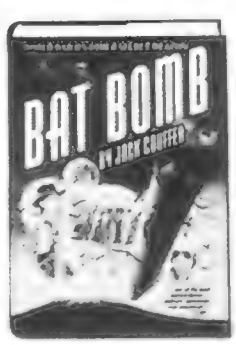

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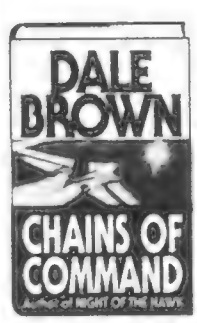

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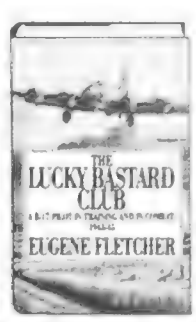

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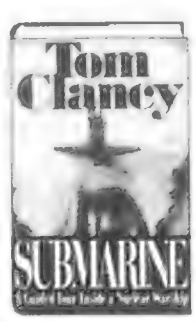

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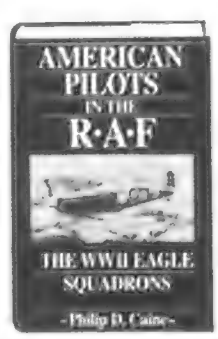

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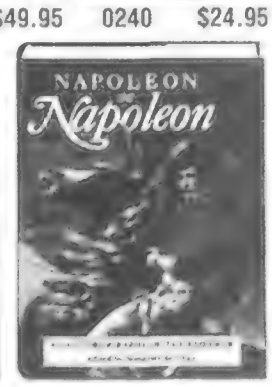

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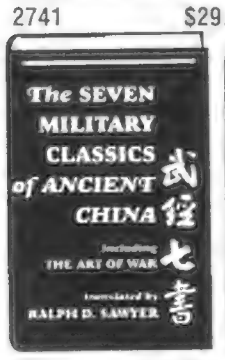

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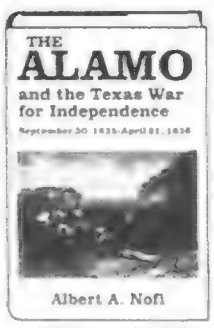

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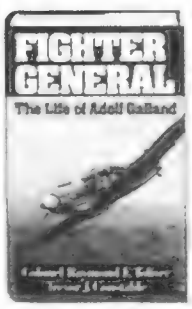

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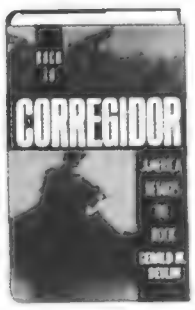

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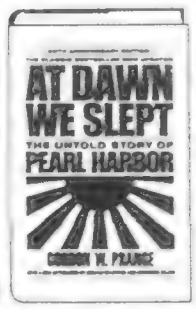

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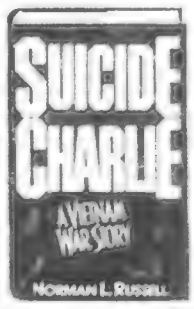

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In the Words of a Spy

"A prisoner never gives up hope. He is always waiting for some miracle to happen. A person would go completely crazy in prison if there wasn't, in the back of his mind, this hope of getting out, some way or the other."

Francis Gary Powers recorded these thoughts in a journal that he kept while imprisoned after his U-2 spyplane was shot down over the Soviet Union on May 1, 1960. Charged with espionage and tried in the Soviet Union, the CIA pilot was sentenced to 10 years, but he was released after 21 months when he was exchanged for Soviet spy Rudolf Abel. During his captivity, Powers used the journal to document the emotional ordeal of confinement. In addition to the journal, Powers kept a diary in which he detailed the monotony of prison life.

Last November, Powers' widow Sue and her two children Dee and Gary donated the journal, diary, and many other items to the Museum. They decided to make the donation after Karl Schneide, collections manager for the aeronautics department, visited Sue Powers' home in Sherman Oaks, California, a little more than a year ago. Sue, who has never remarried, had made her house into a virtual shrine to her late husband. Says Schneide: "It's one of those classic cases where a curator finds people that saved everything."

When asked why she finally decided to part with some of her husband's possessions, Powers replies: "It's been 16 years since Frank died and I just thought it was time. Every time you mention U-2, then Frank goes along with it. I'd kept them long enough."

Along with an assortment of flightsuits, a needlepoint rug (above) that Powers made in prison, and a telegram Soviet Premier Nikita Khrushchev had sent to Powers' father saying that he could not prevent his son from being tried, Schneide is especially pleased to have received the prison journal and diary. Aside from some excerpts that appeared in Powers' 1970 book *Operation Overflight,* the bulk of the material in these two documents has never been seen.

Powers passed his time in prison by reading, going for walks in the prison yard, making envelopes, and writing letters. His periods of depression were eased somewhat by the companionship of a good-hearted Latvian cellmate, who showed him how to make the rug. Powers also spent many hours filling up his diary and journal. On December 15, 1960, he wrote in his diary: "Fed pigeons during walk. Am partial to a white pigeon and try to feed him more than the others. He is too shy and lets the other pigeons take his food. Potatoes for supper."

In the journal, which was written in a Russian notebook that Powers obtained through prison employees, he describes his overwhelming sense of hopelessness and uncertainty. Gary Powers, who is lobbying the U.S. Postal Service to put his father on a stamp, says that his father's journal details "what the trials and hardships were. What the feelings of despair were. How any little sign of hope that he was going to be released would be magnified, and then all of a sudden the tremendous letdown he'd experience when it didn't happen. For me, it was very heartwrenching."

GARY KUEFFER

In September 1961, Powers wrote in the journal: "I am afraid I will never be a Kennedy supporter in the future. It seems to me that Kennedy would have tried to get me released. I don't expect him to go out of his way to help me, but I feel that I would have been released long before now if he had made the slightest effort when he met with Khrushchev." On January 31, 1962, Powers despaired of ever being released: "I am a nervous wreck because of this, and as hard as I try, I cannot keep from thinking about it. I need help badly! But who can help?" These were the last words he wrote in the journal. Ten days later Powers was exchanged for Abel on a bridge linking East and West Berlin.

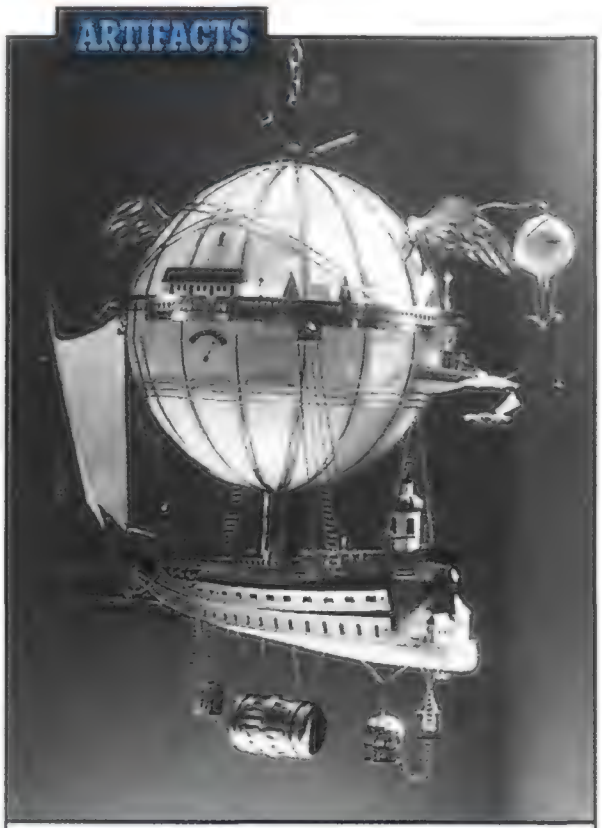
As a spy who had been exposed, Powers' flying days at the CIA were over. Wanting to get back in the cockpit, he left the agency in October and went to work test flying his beloved U-2s for Lockheed's Skunk Works. After *Operation Overflight* was published in 1970, Lockheed fired Powers. Unknown to him, the CIA had been paying his salary, and the agency did not approve of the book's publication.

Six years later, Powers took a job flying a helicopter and doing traffic and weather reports for a Los Angeles TV station. On August 1, 1977, he died when his helicopter ran out of fuel and crashed.

In May Powers' possessions will be exhibited underneath a U-2 hanging in the Looking at Earth gallery. Although he never wanted to be famous, Francis Gary Powers would no doubt approve of his things being displayed near the aircraft he loved flying more than any other.

—Diane Tedeschi

ARTIFACTS



MARK AVINO

Half ship, half balloon, this fanciful model of a self-contained aerial community was designed by French aeronaut Etienne Robertson in 1803. Robertson's design was never realized, but this four-foot model shows his vision of a floating city complete with telescope, church, and living quarters. Located in the Early Flight gallery, the model was donated to the museum by Patrick J. Sullivan in 1976.

Museum Calendar

Except where noted, no tickets or reservations are required. To find out more, call Smithsonian Information at (202) 357-2700 Mon.–Sat., 9 a.m.–4 p.m.; TTY: (202) 357-1729.

February 5 Monthly Sky Lecture. Einstein Planetarium, 9:30 a.m.

February 4–18 Science Fiction Film

Festival. Feb. 4, *The Rocketeer;* Feb. 11, *Meteor Man;* Feb. 18, *Raiders of the Lost Ark.* Langley Theater, 7:30 p.m. $1 admission.

February 10 Robert Smith will speak on the troubled history of NASA's Hubble Space Telescope. Einstein Planetarium, 7:30 p.m.

February 15 "50 Years of Blacks in Aviation." Langley Theater, 7:30 p.m.

February 16 Exploring Space Lecture Series. Wesley T. Huntress Jr., associate administrator for space science at NASA, will discuss missions to the outer solar system.

February 24 G.E. Aviation Lecture. A test pilot for the XB-47, Robert M. Robbins will talk about his days at Boeing. Langley Theater, 7:30 p.m.

March 5 Monthly Sky Lecture. Einstein Planetarium, 9:30 a.m.

March 9–11 "Mutual Concerns of Air and Space Museums." Seminar for museum professionals; registration closes Feb. 14. (202) 289-9113.

March 11 A new exhibit, "Patty Wagstaff—National Aerobatic Champion," opens in Gallery 208.

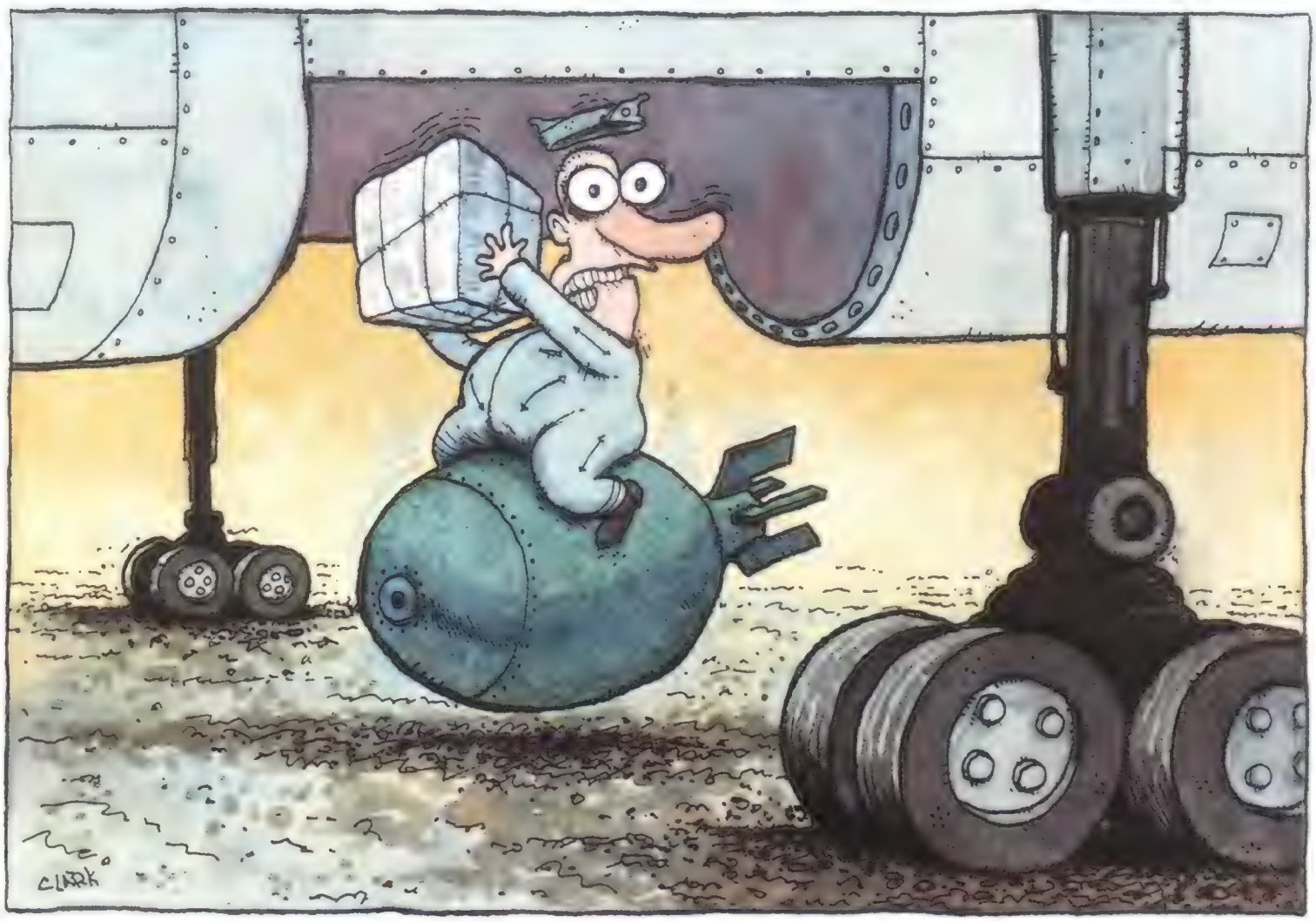
March 16 Exploring Space Lecture Series. Alan Stern of the Southwest Research Institute will discuss the Pluto-Charon system. Einstein Planetarium, 7:30 p.m.

March 24 G.E. Aviation Lecture. Speaker William K. Kershner runs a flight school in Sewanee, Tennessee. Langley Theater, 7:30 p.m.

Awards Night

Last October 22, Olive Ann Beech and Compton J. Tucker were awarded the 1993 National Air and Space Museum Trophy in a ceremony sponsored by Martin Marietta. A family member accepted the award for Beech, who died last summer on July 6. She was honored for her leadership at the Beech Aircraft Company, where she became president and chief executive officer after the death of her husband Walter in 1950. Tucker, a physical scientist with the Earth Sciences Directorate and a fellow at NASA's Goddard Space Flight Center, received his trophy for his study of Earth's environment from space.

The Crab Meat Bombed



DAVID CLARK

I never eat seafood. During many years of skin diving, I had a long-standing agreement with the creatures of the sea: I wouldn't eat them if they wouldn't eat me.

But I figured I should take advantage of the opportunity to bring a big frozen block of king crab meat back to San Francisco. According to the personnel at Adak Naval Air Station in the Aleutian Islands, it was a real bargain, purchased right off the boats at Finger Bay.

It was the mid-1960s, and I had been vegetating on Adak Island for six months as the technical rep for the Lockheed P-3 Orion's Allison engines. Now that I had completed my tour and was going back to Moffett Field, I planned on carrying the frozen crab meat with me. I was sure my San Francisco friends would appreciate a generous chunk of the delicacy.

The crab boats brought their catch into Finger Bay for shelling, cooking, and freezing. I went to the boats early on the morning of my departure and asked if I might buy some. The fishermen produced a huge rectangular slab that looked and felt like white armor plate. It weighed 35 pounds. They said it was the only size they had.

I should have figured, with just a little mental calculation, that at one pound of crab per friend I needed 35 friends on which to unload the stuff. I didn't have that many friends. I could only think of three. That meant I would have to find 32 crab-loving strangers before the catch of the day spoiled.

The crab boat people could offer me nothing to contain the 35-pound block, not even a big paper bag. From the trunk of my dilapidated car, I retrieved some crumpled and soiled newspaper. I bundled the crab meat with it, tied it with string, and left for the flightline.

The P-3 anti-submarine warfare airplane in which I was flying was to carry a leaking nuclear depth charge back for repair. The term "leaking" apparently did not mean leaking radioactivity. I had flown sitting next to "leaking" nuclear weapons before and was never required to wear any sort of shielding.

The depth charge was to be shackled to a bomb rack in the weapons bay. I figured the weapons bay was also a splendid place for my crab meat. At altitude, the temperature would be far below freezing, keeping the crab from thawing—unless someone accidentally turned on the weapons bay heat.

The pilot okayed my stowing the crab meat in the bay. Carrying my ridiculous newspaper-wrapped bundle, I headed for the airplane, which was sitting on the ramp with its weapons bay doors open. I smiled uncertainly at a high-ranking Moffett Field officer and his entourage, who were chatting with the Adak brass. They looked at me and my messy package. The Adak nuclear weapons officer, who up to this time had been a close friend, studiously avoided any sign of recognition, staring alternately at his feet and the dim horizon of the Arctic dawn.

I edged under the weapons bay door, standing up carefully inside so as not to bash my head on the nuclear depth charge, which was hung on the forward starboard rack. In the security of the

semi-dark cavity in the P-3's belly, my numb fingers wrestled with the slab of frozen crab. The unwieldy package defied installation. I wrapped some lightweight rope around the crab and wrapped even more around the bomb rack, leaning against the nuke to gain more purchase to draw the rope taut. As I tied the last of my dozens of granny knots, I felt the depth charge wobble a little within its constraints.

The crab meat seemed to be securely attached to the rack, and after a test wiggle to check security, I bent down and exited the bomb bay.

The officers from Moffett were saying goodbye to their Adak hosts, and as I walked toward them, I heard a dull, heavy thud. It sounded like someone had dropped a lead safe on the ramp. I felt it through the thick soles of my flight boots. The awful silence that followed and the shocked stares of everyone on the ramp told me what had happened even before I looked back.

I turned and saw the nuclear depth charge lying on the concrete. After a millisecond's hesitation, the nuclear weapons officer rushed over to it, squatted, and placed an ear against the weapon while everyone held their breath. I had no idea what he was listening for, but I knew if he jumped up and ran like hell we were all in big trouble—though only briefly. The nuke's yield was enough to ruin the day of everyone on Adak Island.

Thoughts of what might be coming flashed through my mind. Would I see an intense bright light before I was vaporized? Or would only the conventional explosive portion of the weapon detonate, perforating me like a sieve?

Finally, my former friend stood, smiled wanly, and signalled an "okay" with his thumb and forefinger. The sighs of relief were audible. Then accusing eyes turned on me, and the murmurs began. Murmurs, without a doubt, expressing sharp opinions as to what I had managed to do while up in the weapons bay wrestling with the collective body parts of dozens of dead crabs.

The nuclear weapons officer had turned back toward the nuke, which was lying there like a big finned green salami. I glanced furtively at him. He was distinctly pale. Out of the corner of his mouth he growled, "What the hell did you do up there? How did you manage to pickle this damned thing out of the bomb bay? What did you screw around with, you knucklehead?"

"Nothing!" I declared. "Nothing, I swear! I just *leaned* against it."

"You did more than just lean against it," he insisted.

"No, honest, I just leaned on it when I was tying up my crab meat. Hey, look, it was already in need of some kind of repair, wasn't it? So, let them fix the original problem, then knock out any dents."

"If I had any say in the matter," he replied, "I wouldn't even let you on the airplane."

The dinged depth charge was re-hung in the weapons bay. An inane thought crossed my mind: *What if now my crab meat falls out?*

The weapons bay doors were closed and we all boarded the airplane. On the flight to Moffett, only the flight engineer spoke to me. He came back for a cup of coffee and asked pleasantly, "Do you do this often?"

"You mean fly back and forth between Adak and Moffett?" I said, grateful for his interest.

"No, salvo nuclear weapons out of bomb bays onto flightlines."

I was definitely *persona non grata.* Sitting at one of the scanner windows, I spent most of the time over the Gulf of Alaska counting the rivets on the wing and picking non-existent lint off my flightsuit.

By the time I got into downtown Mountain View, the crab meat was thawing. Actually, in the California sun, it was festering.

Since the center of the block was still frozen, I needed a hacksaw to cut off portions for distribution. I stopped at a friend's house and borrowed one. The guy's wife, after seeing the mess in the soaked, tattered newspapers, made me cut it on the front steps. Then, getting a whiff of the stench, she declined my offer of free king crab meat altogether and told me to keep the hacksaw *and* the crab meat and take it all someplace else. Things deteriorated from that point. No one wanted any crab meat. No one even wanted me in his house.

The final blow came when I found out that in San Francisco, king crab meat was selling for 40 cents a pound less than I had paid at Adak.

Later, I racked my brain trying to figure out why the nuke fell out. It had to be incomplete engagement of the weapon storage shackles when it was hung. If it had not fallen out after I was fooling around with my crab meat, would it have dropped out on takeoff? Would it have torn through the weapons bay doors? Would that have caused the P-3's nose to pitch up? How about a sharp pitchup just after liftoff, at a critically low airspeed and altitude? Not an appealing scenario. Considering all the possibilities, including having the damned thing fall smack-dab in the middle of the Presidio, I'm glad I had jostled it into its fail-safe position: lying on the concrete at Adak.

—O.H. Billmann

Gramps

As children growing up in the Doolittle household, we were relatively unaware of the public persona of Jimmy Doolittle. The man we knew was Gramps, and what I remember best about him was that he knew how to play.

I can still see him sitting on the couch in the living room surrounded by three little girls who were fixing his hair. For as long as I can remember Gramps was bald, but it was great fun to put pink sponge curlers in those long gray eyebrows.

In 1959 my grandparents moved from San Francisco to Santa Monica, California. For the next 20 years the house in Santa Monica was the first real home for the nomadic Doolittle clan. I loved to walk down the long hallway, one side of which was lined with bookcases filled with wonderful books on hunting, fishing, aviation, world history, military science, and international cooking. The opposite wall was covered with autographed photos of my grandparents' friends—Winston Churchill, Amelia Earhart, Charles Lindbergh, and hundreds more. I enjoyed hearing the stories behind the pictures, and the textbooks I would later read in school were filled with these people.

My grandmother was a fine cook. Meals frequently were large feasts. Dinnertime would find us sitting at the intricately carved Chinese teak table in the dining room, often the scene of great revelry. It might start with someone tossing a roll or Gramps mashing someone's pie. The excitement would escalate until my grandmother would calmly raise her spoon to her eye, as if using a lorgnette, and instantly bring us all to order, even her husband.

Gramps had an insatiable thirst for knowledge. He often got up during a family discussion to look up a word or find the answer to a question, and when he read he kept a dictionary by his side. He was equally rigorous in maintaining his health. Through his mid-80s he walked the seven flights of stairs to his office twice a day. Daily walks were part of his routine until the last weeks of his life, when illness confined him to bed.

COURTESY JONNA DOOLITTLE HOPPES

But what keeps me company in the void created by his passing is remembering his marvelous sense of humor. One afternoon, while visiting my grandmother, Gramps and my young daughters took off on a walk. After a while I worried that they had been gone too long. Fearing that the girls would tire him, I began walking the neighborhood looking for them. In a few minutes I saw them coming up the hill, Gramps walking without support, and the two girls using his canes. They had been playing "school" in a little chapel, and at 91, Jimmy Doolittle was still a somewhat mischievous student.

In 1980 Gramps joined me and one of my daughters on a long car ride, during which his great-granddaughter learned to unbuckle her car seat and unzip the diaper bag. Twice my 83-year-old grandfather climbed into the back seat to restore order. After seven hours we pulled into his driveway. As he climbed out of the car he grinned at my grandmother and said, "Joe, let's don't have any more children."

Joe was supportive and helpful to her husband all of her life. She had an exceptional memory, and my grandfather often turned to her for information about people they had met and events they had shared. She spent her life giving to others. She said that if she didn't lift someone's spirits every day, she had no right to live.

In 1984 she suffered a massive stroke that left her partially paralyzed and unable to speak. After that, my grandfather, having traveled all his life, spent almost every day at her side. The image of him sitting with her and quietly holding her hand will stay with me forever. She died on December 24, 1988, their 71st wedding anniversary.

Last Labor Day, my grandfather suffered the first of a series of strokes. Over the next few weeks, with his health failing, he was nonetheless aware of the strength of the love that surrounded him. He died at home on the afternoon of September 27.

The funeral services at Arlington National Cemetery were beautiful. There was not a dry eye when four F-16s flew the missing-man formation overhead, followed by four F-15s, a C-141, and a B-1B. After a moment's pause, a lone B-25, the airplane my grandfather chose for his famous Tokyo bombing mission, flew over.

Afterward, I stood in front of the Washington Monument, looking at all the flags at half mast. When I asked my girls what they remembered most about their great-grandfather, my youngest said, "He was happy and he made us happy."

In his autobiography he wrote, "One of the privileges of age is the opportunity to sit back and ponder what you've seen and done over the years. In my nine-plus decades...I have concluded that we were put on this earth for a purpose. That purpose is to make it, within our capabilities, a better place in which to live. We can do this by painting a picture, writing a poem, building a bridge, providing help to those in need, and in thousands of other ways. The criterion is this: If a man leaves the earth a better place than he found it, then his life has been worthwhile." Jimmy Doolittle surely fulfilled his purpose.

—Jonna Doolittle Hoppes

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Washington, D.C. April 17-20: Assist curators in preserving Polynesian barkcloth.

THE LATEST WORD ON TOURS, EXPEDITIONS AND LEARNING ADVENTURES

GROUNDED:
The Aggressor Squadrons

An inside look at the downfall of the Air Force's elite enemy simulation units.

by Reina Pennington

It seemed like a good idea at the time. Take a group of crack fighter pilots, weapons school graduates, and guys who flew in combat in Vietnam. Give them free access to intelligence sources so they know exactly what the enemy's doing. Give them some airplanes that look and act like enemy airplanes. Then let them go out and fly against other Air Force pilots—show what the enemy might look like in a real war. That was the idea behind the creation of the U.S. Air Force's Aggressor squadrons in 1972.

For combat pilots, the first 10 missions are the riskiest; the Aggressors, together with the Air Force's "Red Flag" war simulations, were designed to give pilots those 10 missions in peacetime. The program rapidly expanded: during their 18-year existence, the Aggressors flew more than 200,000 sorties and made more than a thousand training deployments to U.S. and Allied units around the world.

But within a few years of their creation, some people—very high ranking officers and line pilots among them—began to see the Aggressors as a plague rather than a cure. Some said the Aggressors had ego problems; they pushed young pilots too hard; people got killed.

They were accused of manipulating intelligence data to support outrageous tactics; at the same time, some senior officers pressured them to ignore developments in Soviet tactics that were seen as too dangerous to duplicate.

In the late 1980s, the perceived end of the Soviet threat led to severe cutbacks in the military, and the Aggressors seemed to have outlived their usefulness. In 1990, the Aggressor program—arguably one of the most innovative air training programs in history—was disbanded. Today, many former Aggressors believe that decision may have been a costly mistake.

From the beginning, it was a tough sell. The creation of a squadron specifically devoted to the simulation of enemy air combat tactics had never before been attempted; by the standards of the Air Force of those days, the concept was radical. "We got thrown out of almost everybody's office because [they thought] the Aggressor idea was too dangerous," says Randy O'Neill, a former instructor at the Air Force's Fighter Weapons School who, along with fellow instructor Roger Wells, was instrumental in the founding of the program.

Wells, the outstanding graduate in his class at the Fighter Weapons School, had been interested in the idea since 1966, when he had flown F-4s in Vietnam. He still remembers the critique he wrote of the training he'd received: "You taught me everything there is to know about how to fight against another American airplane, but you taught me absolutely nothing about how to fight against the enemy." His experiences clearly pointed him to the need for, in Air Force lingo, "dissimilar air combat training"—training against aircraft different from those the pilots were flying. To Wells, these would ideally be actual enemy aircraft flying enemy tactics. In the early 1970s, O'Neill and Wells began to preach their radical gospel.

On October 15, 1972, their persistence paid off: the 64th Aggressor Squadron was activated at Nellis Air

Until they were disbanded in 1990, the Air Force's Aggressor squadrons emulated the Soviets in their squadron patches (above), their paint schemes (opposite), and—most importantly—their air combat tactics.


47
58
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TEST PANEL
1- PUSH LATCH TO OPEN DOOR
2- PULL HANDLE OUT & IT
TO JETTISON CANOPY

Force Base in Nevada. It would provide adversary forces for Air Force exercises, train new Aggressors, and send Aggressor teams on deployments to operational wings to give academic briefings and fly against the local pilots.

To simulate the primary threat aircraft of the time, the MiG-21, the Aggressors would fly 20 Northrop T-38s on loan from the Air Training Command. Wells' dream of actual MiG-21s would have been far too expensive. The two-seat supersonic trainer resembled the MiG in one particularly important way: its engines did not smoke. In training against other F-4s in preparation for Vietnam, American pilots had become dependent upon spotting the F-4 engines' trail of smoke, visible up to five miles away.

So now the Aggressors had a product—but still no market. "Probably the hardest thing we ever did was to find somebody who wanted to host us for that first deployment," notes Lloyd "Boots" Boothby, the squadron's first commander. "It was like pulling teeth to get anybody to do it." At the time, accident rates in the tactical air forces were high. "Wing commanders were scared to have us come," says Ron Iverson, one of the original Aggressors and later a two-star general. "All they'd heard was there was a bunch of guys out at Nellis flying T-38s, they're going to come and whip up on your guys, and your accident rate will probably go even higher."

Wing commanders were also reluctant to be first because they knew it would put their wing under a microscope. As O'Neill points out, "We knew that when we made our first deployment, everybody and their brother would come down from the Pentagon. Everyone waiting for us to go kill ourselves, the naysayers—we knew they'd be out in force."

Finally, an F-4 replacement training unit at Florida's Homestead Air Force Base agreed to serve as the first host. The problem was the pilots there were just learning to fly F-4s. "I was really nervous about that," O'Neill admits.

However, the weapons officers at Homestead devised a special program of workup flights for the crews selected to fly against the Aggressors, and in July 1973 the first Aggressor deployment "went off beautifully," O'Neill recalls. That broke the ice. Soon the Aggressors were fulfilling a heavy schedule of "road shows" to operational wings, and a second Aggressor squadron, the 65th, was created at Nellis. The U.S. Air Force in Europe (USAFE) created the 527th Aggressor Squadron at Alconbury Air Base in England, and the Pacific Air Force opened the 26th Aggressor Squadron at Clark Air Force Base in the Philippines.

By the mid-1970s, the Aggressor program seemed to be on the fast track to success. In 1975 the Aggressors got a new fighter: the F-5E. Built for export, the F-5 was small and sleek, with simple avionics. It could achieve supersonic speeds only in short bursts, and it had tiny fuel tanks. The only weapon system it had was its guns. But in terms of performance, the F-5 was a better simulator of the MiG-21 than the old T-38.

Once they were accepted, the Aggressors visited every operational wing two or three times a year, providing both dissimilar air combat training and academic training. In popular parlance, the Aggressors became known as "gomers," a slang word for "enemy" in Vietnam.

The early Aggressor road shows are widely remembered for the quality of training they provided. Jerry "Sparky" Coy, former assistant operations officer of the 65th, says that during a typical road show, six aircraft and seven or eight pilots, plus support personnel, deployed to the host base. About 20 pilots from the host squadron were designated to fly against the Aggressors; generally the host pilots flew once a day, while the Aggressors themselves flew two or three sorties a day. "The host pilots were usually so wrung out after one, that was all they could handle," Coy says.

The type and size of the missions were always tailored to the host unit. Typically for the first few days of a road show the training consisted of a series of single Aggressors flying against sin-

CHAD SLATTERY

DAVID LEESON

For Lloyd Boothby (above; now a sales manager at a Las Vegas hotel) and Randy O'Neill (left), the Air Force's performance in Vietnam pointed to the need for combat training with dissimilar aircraft. For most of their 18 years, the Aggressors accomplished this with the Northrop F-5 (right), bedecked in large, Soviet-style nose numbers.

gle F-4 crews. Single-ship training flights focused on basic fighter maneuvers rather than specific enemy tactics.

After a few days, the training scenarios might be upgraded to two F-4s against a single Aggressor. Later in the deployment, or if the host pilots were more experienced, two Aggressors would square off against two host pilots. At the leader's call of "Fight's on!" the Aggressors would simulate Soviet air combat tactics, based on classified intelligence information. This would include flying typical Soviet en route formations and diversionary tactics, and simulating the ranges and aspects at which enemy missiles could be fired.

After each flight, the Aggressors conducted debriefings, drawing every turn and maneuver used during the engagements on a blackboard. Aggressor pilots were specially trained to recreate a sortie in its entirety. In the days before onboard videotape, they relied on memory, brief clips of gun camera film, and tape recorders. Every pilot had his own memorization techniques. Most commonly, Aggressor pilots taped a running monologue during the flight. The maneuvers used, their effectiveness, and the "learning outcomes" were all discussed in the debriefing.

I first encountered the Aggressors as a second lieutenant intelligence officer at Hill Air Force Base in Utah, when they came to fly against one of our F-4 squadrons in 1979. I sat in on every briefing and was enthralled. I had not known that the Air Force had a unit that simulated the Soviets—certainly no one in the intelligence division had mentioned it. Having majored in Soviet studies in college, I couldn't imagine a better job than Aggressor intelligence officer. I cornered the detachment commander, Ron Iverson, in the bar at the officers' club and tried to convince him that my background uniquely qualified me to be the next Aggressor intelligence officer. Within a few months, I'd received special permission to curtail my tour at Hill and transfer to Nellis.

The Aggressors always worked at the junction of operations and intelligence—sadly, a relationship that in the Air Force has usually been weak. The intelligence community was definitely a world apart from the flying community. First there was the problem of security clearances: most pilots were not cleared for highly classified information. Second, there was the physical separation of intelligence and operations. Intelligence personnel worked in vaults, usually at wing headquarters, behind a series of doors secured by locks and entry codes. Pilots couldn't just walk in and ask questions.

GEORGE HALL/CHECK SIX

Tactically relevant intelligence was almost completely lacking during and immediately after the Vietnam war and the Aggressors were among the first to try to remedy that situation. Boots Boothby remembers telling the commander of the Tactical Air Command that there was "a huge, huge wall between operations and intelligence. And the reason it's there is because no fighter pilot was ever going to admit there was something he doesn't know. And intelligence doesn't have the aptitude to know what the pilots need. They're a library, and until someone asks for a book, they don't care what's on the shelf." It was clear to the Aggressors that pilots had to get into the intelligence world. That meant many Aggressors had to get special intelligence clearances. But it cost them; they became ineligible for combat duty until a year after the clearance had expired. It could compromise too many sources if someone with a special intelligence clearance were captured.

Each Aggressor was required to become an expert in some facet of enemy capabilities. Pilots produced briefings on their specialties—the training of Soviet pilots, their tactics, what future threats would likely entail—and presented them during deployments.

MIKE KITTRELL

These classified academic briefings became one of the hallmarks of the Aggressor program.

Throughout the 1970s and '80s, the Aggressors were a cornerstone of Air Force air-to-air training. Any time you talked about realism, you were talking about the Aggressors. Even articles in Soviet military journals noted the benefits of the Aggressors. At the same time, problems had begun creeping into the program.

The Soviets were making steady, if incremental, improvements in tactics and technology. The United States' capabilities were improving almost exponentially. But no provision had been made for automatically upgrading the Aggressors to match the threat. By the late 1970s the Soviets had introduced the MiG-23 Flogger as their frontline fighter; the U.S. Air Force began fielding the F-15 and F-16. Yet the Aggressors continued to fly the outmoded F-5, an increasingly poor simulator against an increasingly capable opponent. It was almost impossible for them to keep pace with the changes.

The F-15's arrival changed the nature of the road shows. In the early days, when the Air Force primarily flew the F-4, most training with the Aggressors involved small engagements—rarely more than two aircraft on each side.

JOHN AMRHEIN/NORTHROP

The Aggressors' ubiquitous red star was an homage to the Soviets; some Aggressors today believe their strong identification with the former superpower ultimately limited the value of the training the squadrons provided.

There was a lot of emphasis on close-in, within-visual-range fighting. This was because the F-4 had been built as a dual-role fighter and was largely used in that capacity in the Air Force, with the bulk of the training focusing on air-to-ground rather than air-to-air combat. But the F-15 was built specifically for air-to-air combat, and the new F-15 host pilots were already conversant in basic fighter maneuvers and more advanced air combat training. In some people's minds, the need for pure instruction from the Aggressors had diminished.

The superior capabilities of the F-15 also meant "the basic mission changed," Randy O'Neill stresses, "because air-to-air now doesn't involve getting into a phone booth with a pocket knife, like it did back then. A properly flown F-15 will never close; he'll just shoot you down from 30 miles away—no further questions." Flying the F-4, only really outstanding pilots had been able to beat the Aggressors early in their training, but with the F-15, most pilots could win. "When we started going to the F-15 units, some squadrons became so proficient that we had to do everything we could just to keep our heads above water," Hal Smith remembers. Smith is a soft-spoken, highly intelligent former Aggressor who had been a pilot in a high-risk covert program in Laos during the Vietnam war.

The F-16 was yet another challenge. "With the F-16s, now you don't have even the size advantage" of the small F-5, says Earl Henderson, a former operations officer of the 64th and a charter member of the Aggressors. The F-16 was just as small and hard to see, both visually and on radar, as the F-5, and its performance in air combat was far superior. "The F-16 could turn up its own fanny. It's tough to 'be humble' against that little guy, you know?" Henderson adds, in reference to one of the Aggressors' mottoes.

Technological improvements also began to supplant another facet of Aggressor training. Traditionally, the Aggressors were known as masters of debriefing—"chalk talks" that reconstructed the mission and discussed lessons learned. In the 1980s, automated Air Combat Maneuvering Instrumentation (ACMI) ranges began to replace the blackboard. Pods mounted on fighters relayed information through ground receivers, allowing a master computer to track a fight as it occurred. During the debriefing, the air battle was replayed on a large screen in a 20- to 30-seat theater, in a format a lot like a video game. The ACMI displays could show the relative positions and ranges of each aircraft, how fast they were going, how hard they were turning, and who fired when. It permitted greatly increased accuracy in debriefing.

The problem, according to some Aggressors, was that the quality of the debriefings declined. There was no formal program for using the ACMI in debriefings. "It's a great machine, but it can be too distracting," says Mark McKenzie. A tall man out of the "strong and silent" mold, McKenzie flew as an Aggressor in Europe, the Pacific, and the states. "Some guys would just sit back and play it and you'd lose control of the debrief—guys would be arguing about shots. The debrief could just fall apart."

Another problem was that ACMI debriefs brought in more observers. Traditionally, Aggressor debriefings occurred in squadron briefing rooms that could accommodate only the pilots involved in the flight. ACMI facilities could seat a lot more observers. "You'd lose the honesty of the debriefing, somehow," McKenzie says. "It's more difficult to have an honest, frank environment when you've got a cast of thousands in there watching what's going on."

Personnel issues—the source of the ego and attitude problems sometimes attributed to the Aggressors—were always a thorny question. From the start, there was a dispute over how the Aggressors should be manned. Roger Wells had dreamed of assembling the Aggressors of "the best fighter pilots in the United States Air Force, the greatest weapons school instructors that walked the face of the earth." Today, he believes staffing problems were what led to the Aggressors' demise. In his Alabama drawl, he says, "before they were ever operational, I knew they were doomed."

While most people never expected the Aggressors to be manned only with weapons school graduates, they did believe that at a minimum, only experienced fighter pilots should become Aggressors. "We could not sustain the quality we needed," says Earl Henderson. A big man with the sort of face you immediately trust, Henderson is universally admired in the Aggressor community. He remembers that "the personnel system said: you guys can't just keep taking the top talent—that's raping the operational community."

O'Neill says he bitterly resisted watering down the entrance requirements, but the Aggressors couldn't do much about it. He recalls the case of one pilot: "His courage was undoubtedly very high, but his skill at flying fighters was substandard. So consequently he washed out. Well what do you know, about six months went by, and the new [director

CHAD SLATTERY

Although Roger Wells (left) was instrumental in the founding of the Aggressors, he was not asked to serve with them. "Needless to say, that broke my heart," he says today. Both he and charter Aggressor Earl Henderson (right) believe staffing problems led to the Aggressors' demise.

of operations] who came in reinstated him in the program and ordered us to graduate the guy. So the standards were getting all terribly twisted."

By the late 1970s, as Henderson remembers things, the Aggressors were being sent a large percentage of pilots with only one fighter assignment under their belts. "You get a kid who was King Kong in his F-15 outfit, and now he's got to fly this fighter that's ten years older than what he was flying, with two-thirds the maneuvering capability, and he's going to go out and get his ass kicked by these average guys he's been flying against," Henderson says. "I think it was disastrous for a number of reasons. These kids didn't have the emotional maturity to do the mission, to be a training aid, to lose, and to like it when they lost."

Yet that was the purpose of the Aggressors. As Ed Clements, another charter Aggressor, explains, "The best possible feeling for an Aggressor was to come back from a flight out of breath, tired, and sweaty, knowing he used every tactic, employed every advantage he knows, and still did not come away with a 'kill.' "

Learning to be that sort of instructor was extremely difficult for some of the younger pilots. In operational units, fighter pilots do everything they can to fight and win. But in the Aggressors, they were asked to pull their punches, to keep the fight to a level where the opponent could learn the most. "Some of them weren't able to do that without making it very obvious they didn't like it," Henderson says. "They were young buck warriors. They wanted to go out and kick some ass, take some names."

Being a good Aggressor demanded more than just experience, maturity, and flying skill; it also required a certain type of personality. "You think of an Aggressor as a macho fighter pilot, but it's more than just stick-and-rudder skills," Mark McKenzie says. "The key is being able to steer a debrief or conversation toward valid learning. You have to have that core, innate ability to listen, interpret, and articulate things in an unpoliticized way."

It's hard to say where or why some of the Aggressors began to lose their "be humble" attitude. When I first arrived at Nellis in 1980, I went through the ground academics course with one class of Aggressors. Someone designed a patch for our class that prominently displayed the words "be humble" in the center. Across the top of the patch, however, was written "Oh Lord, it's hard to..." At the time I thought it was just a play on the popular country song, but later I wondered if it indicated deeper troubles in the Aggressors.

Concerns about flight safety also continually hounded the program. "Flying safety and combat capability are diametrically opposed," says Boots Boothby. "I just wish to hell somebody would explain to people: Who cares about an accident rate? You kill them in wartime or you kill them in peacetime; the ones

RANDY JOLLY AERO GRAPHICS

who get killed are the ones who aren't going to make it. And they don't pay you flying pay because you're going to live as long as the other guys."

Boothby's attitude is commonly held but rarely expressed officially (and Boothby himself is quick to note that no accidents occurred under his command). Many fighter pilots believe that combat training is inevitably a weeding process. The more realistic your training, the higher the risk involved—but the result, it is believed, is a much more capable operational force.

"Some commanders were afraid to have the Aggressors around," Jerry Coy recalls. "We were blamed for so much stuff that we had absolutely nothing to

The F-16s the Aggressors finally received were a mixed blessing; they performed better than the old F-5s, but they couldn't provide the dissimilarity necessary for training.

do with." The problem, in Coy's opinion, was that the Air Force got carried away with air-to-air training. Sometimes the Aggressors flew against units that had little or no preparation in air-to-air training. In the excitement of the fight, some host pilots who were unaccustomed to the demands of combat found themselves in over their heads. In maneuvering to avoid being "killed," some stalled or spun their aircraft; a few ended up dead. One notorious pair of accidents occurred in the early 1980s, when the Aggressors were training pilots in a reconnaissance squadron to defend themselves against an enemy attack. On two consecutive days, RF-4s went out of control during training missions. One crew ejected successfully, but the other did not and both the pilot and navigator were killed. "We were doing [basic fighter maneuvers] with these reconnaissance pilots who did nothing more than fly fast, straight and level," Coy says. "We did not recruit those people to come out there and fly, believe me. They didn't know how to handle situations if they let their aircraft get out of control. And the Aggressors were blamed for this." He noted that it was higher headquarters and not the Aggressors who decided which units needed the training.

Another problem was the question of how strictly the Aggressors' training should simulate Soviet tactics. Many Aggressors believed such simulations should have been just the starting point for Aggressor training, not the be-all and end-all. But the Aggressors were told to justify everything they did in terms of simulating the Soviets.

Several Aggressors told me about the time General Wilbur Creech, the commander of the Tactical Air Command, sent his director of operations, Larry Welch, to Nellis in 1978 to investigate the alleged problems with the Aggressors. ("A witch hunt, I guess, would be the best name for it," Henderson says.) Aggressor tactics were closely scrutinized. One young pilot admitted to Welch that a tactic he presented in a briefing had been observed in Soviet training only once: he tried to justify its use as a tactic that a Third World nation could use. According to Henderson, "General Welch said something like 'We can go to war against any Third World country and screw it up ten ways from Sunday, and we're still going to win. But if we go against the Soviets, we'll have only one chance. We'd better be doing it right, based on exactly what the Soviets are doing.' "

PHIL SCHOFIELD

Like many of his former colleagues, Hal Smith (right; now an airline captain) thinks the end of the Soviet Union shouldn't have meant the end of the Aggressors.

The new Adversary Tactics group, under the leadership of Mark Dulaney (opposite), carries on some of the Aggressors' work in a limited fashion.

One Aggressor remembers, "One argument I heard a lot at the time was: We've shown them all this real Soviet stuff. But say we're in day five of the war—aren't the Soviets going to say, 'Hey boys, this is stupid! All our comrades are dying!' And they'll make some natural evolution in their tactics. It's never been observed, but that doesn't mean it ain't ever gonna happen in the war."

"I don't for a minute believe the Soviets would have suddenly become proficient in a real conflict," says Lieutenant Colonel Tom Smith, a USAFE Aggressor and Desert Storm veteran currently working in the Pentagon. But he also questions the value of limiting the Aggressors to observed enemy tactics; he believes the squadrons should have had more flexibility to react to situations in a natural way. For example, the Aggressors operated under rules of engagement that prevented them from dodging long-range radar-guided missile shots simulated by the F-15s and F-16s. "In combat, even Iraqis flying MiG-25 Foxbats proved smarter than that," Smith says. "They weren't clever enough to improvise new tactics during a war, but I think the Iraqis were human enough to dodge missiles on shots they were aware of. The failure of the Aggressors to fill in the gap and behave realistically in an all-aspect environment may have hurt the training value in the long run, and I believe the [U.S.] air community sensed that."

When I was the Aggressor intelligence officer in the early 1980s, I knew there were gaps in our intelligence information. Our collection techniques were often compared to looking through a soda straw. It seemed obvious to me that the Aggressors should give the Soviets the benefit of a doubt and err on the side of better training.

"It could be the whole Soviet concept ended up being the death knell," Henderson says. "We got ourselves locked into this death spiral about being Soviet." When the Soviet Union disappeared, people began to question the value of enemy simulation—and of the Aggressor program.

Yet the biggest problem was probably money. It was tough to keep up with enemy tactics while flying an aircraft that was two generations behind in performance—sort of like getting into a Ford Pinto and trying to drive it like you were in a Corvette. For a long time

the Aggressors tried to continue Soviet tactics by simulating MiG-23s during the beyond-visual-range portion of an engagement; they replicated MiG-23 formations and tactics to try to show what they would look like to an F-15's radar. But there was no way the F-5 could pretend to be a MiG-23 in a visual fight; the Flogger was significantly faster in straight flight, more sluggish in turns, and completely different in other performance characteristics.

Year by year, the decision to spend money for new Aggressor aircraft was delayed. In the Air Force, "bang for the buck" was measured in terms of combat-capable aircraft; the Aggressors just didn't fall into that category. There were too many badly needed improvements in the operational force; training was way down the priority list.

In early 1989 the Air Force finally decided to upgrade the Aggressors to the F-16. Ironically, according to Tom Smith, this might have been the final nail in the coffin. Giving the Aggressors F-16s violated one of the basic tenets of the Aggressor charter: providing dissimilar air combat training. The F-16 "was not dissimilar to the most plentiful aircraft in our inventory," Smith says.

A few months later, the Air Force decided to disband the Aggressors altogether. The Aggressors staged their last road show in August 1990, when the 64th went to Eglin Air Force Base in Florida to train F-15 pilots who were preparing to deploy to Desert Shield. In October 1990, the 64th—the first and, finally, the last Aggressor squadron—closed its doors.

Today, one unofficial remnant of the Aggressors survives: the Adversary Tactics Division of Red Flag. The name was changed to dissociate the unit from the Aggressors, but there are many similarities. The Adversary group flies the F-16C, painted in "threat" paint schemes, and provides a core of air-to-air adversary forces at major Air Force exercises. Adversary pilots still provide academic briefings, and the division is housed behind a door with the traditional red star of the Aggressors. The main difference is in scope. Adversary Tactics consists of six aircraft and 10 full-time pilots. The pilots fly only during exercises; there are no more road shows except for occasional academic presentations.

When I interviewed the Adversary's commander, Lieutenant Colonel Mark "Dula" Dulaney, last October, I asked him, "Who is the enemy these days?" He replied, "I don't know, you tell me. We replicate mostly Russian-type systems because those systems and training are in place in most hot spots in the world that we might face in a future conflict." But they've also added what they call "gray world systems." The

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gray world, he explained, is not "red" (enemy) or "blue" (the United States), but all that other stuff out there—French, Swedish, whatever weapons systems might be sold to and employed by potential adversaries.

In a sense, the lack of a central threat makes the Adversaries' job more difficult than that of the old Aggressors. Based on parameters for various threat aircraft, Adversary pilots restrict their power and maneuvering and use different avionics settings to attempt to replicate an enemy's search and lock-on ranges and so forth. "You're always looking down at your card, saying, 'What are my ranges today?' " Dulaney says. "Yeah. There's a lot of number crunching that goes on."

Speaking in 1992 at the 20th anniversary of the Aggressor's founding, Ron Iverson claimed that because of the Adversaries, "the quality of training that the original Aggressors tried to bring to our Air Force has not changed. The discipline's there, the attitude's there, the 'be humble' is there, and they're doing exactly what we want them to do." But with F-16s, others point out, the dissimilarity has been lost, the road shows have been lost, and, to a large extent, the unique Aggressor academics program has been lost.

An old military maxim is that you will fight the way you train. The Air Force that flew in Desert Storm trained against the Aggressors. How will today's Air Force, with no dedicated adversary training, perform in a future war?

"I think that we're going to live to regret having done away with the Aggressor program," Jerry Coy says. One way the Air Force is compensating for closing down the Aggressor squadrons is by having operational wings train against each other. "With the Aggressors, the only agenda was to make the guys that we were flying against better," says Coy. "And you just don't see that whenever you're doing dissimilar air combat training with another operational unit. That's definitely a shortcoming in the way things are being done now."

Many former Aggressors told me that they believe the Air Force is flying more conservatively today than it was a few years ago. "The gomers are already sorely missed, even I can tell," says Rich Cline, recently retired from active duty. "Every wing commander that has a clue could tell the proficiency of every air-to-air unit has fallen off considerably since the Aggressor program closed up shop." Even Adversary Tactics commander Dulaney notes, "People in the active Air Force continually tell me, 'We really miss the training like we used to have.' I get that every time I go some place."

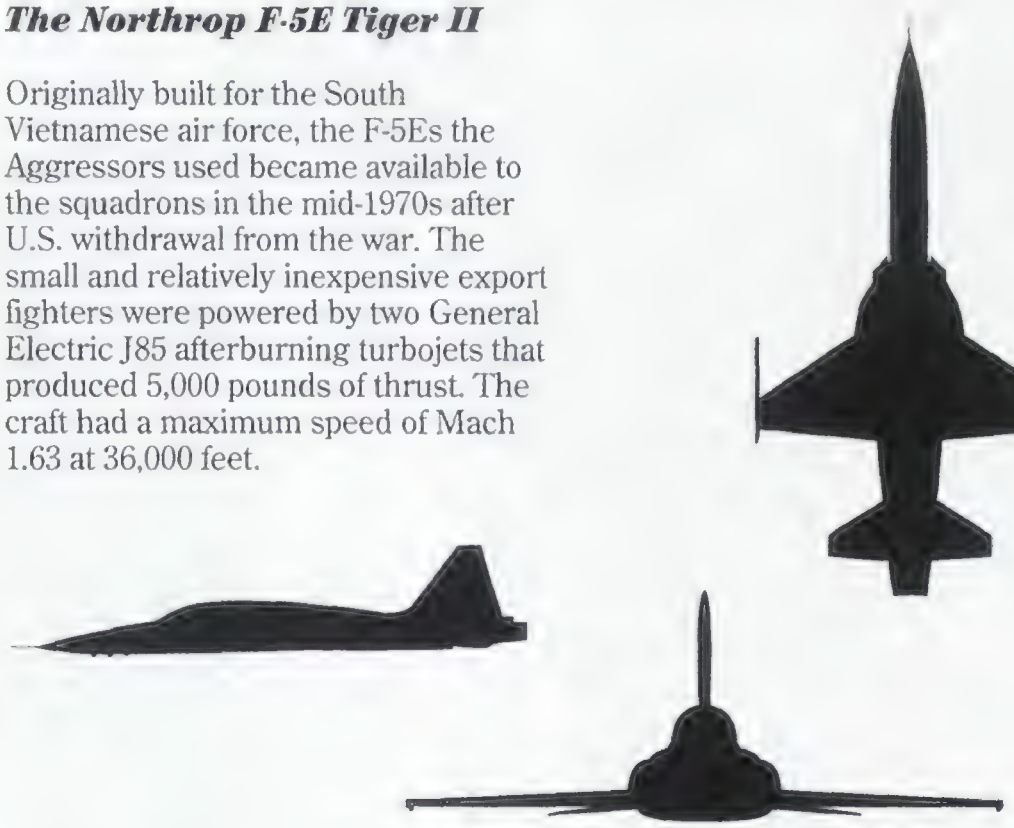
GEORGE HALL/CHECK SIX

"The idea of disbanding the Aggressors because the Soviets go away is ridiculous," says Hal Smith. "It should have been the kind of thing where you had adversaries, and you fight adversary tactics as you saw fit, based on whatever you could dream up." Rich Cline also notes, "There's still a need for a professional air-to-air adversarial unit that puts training first—instead of putting winning first, like every other unit."

"The mental process of learning your

The Northrop F-5E Tiger II

Originally built for the South Vietnamese air force, the F-5Es the Aggressors used became available to the squadrons in the mid-1970s after U.S. withdrawal from the war. The small and relatively inexpensive export fighters were powered by two General Electric J85 afterburning turbojets that produced 5,000 pounds of thrust. The craft had a maximum speed of Mach 1.63 at 36,000 feet.



enemy inside and out and training to a razor's edge to defeat that threat is applicable anywhere against any adversary," says Desert Storm veteran Tom Smith. He compares this process to creating a "learning template" that can be applied to any enemy. "Those of us who fought in Iraq prepared ourselves in just that manner, and the process of applying that learning template worked wonderfully. I'm not sure it would have had we not refined the template against a long-time opponent like the former Soviet Union."

"It doesn't matter if the Air Force has got 13 wings or 39, the Aggressor part of the program is vitally important to the combat effectiveness of the military," Roger Wells says. "I'll tell you what I would do if I was God for a day, if I ran all the military in America. Ten percent of my forces would be Aggressors. Because I would want to be able, every day that I train, to go against a realistic enemy. I'd have Aggressors in the Army, Navy, Marines, Air Force, space force, whatever. That would always be a part of it."

A team of F-5s displays a range of Warsaw Pact camouflage schemes in use in the Aggressors' heyday. Today, the lack of a central enemy to train against has made the Adversaries' job more difficult.

The Great Lunar Quarantine

Welcome back to Earth:

Now get in your trailer.

by Brian Duff

When the Apollo 11 astronauts returned to Earth from the moon on July 24, 1969, they arrived to a reception more appropriate for Typhoid Mary than for the world's first lunar explorers. After their splashdown in the Pacific, an inflatable collar was attached to the bobbing space capsule by Navy frogmen to keep it from sinking. While two frogmen stayed upwind, the third cracked the capsule's hatch and tossed in three Biological Isolation Garments. He then swabbed Betadine, a disinfectant containing iodine, around the hatch and docking drogue, where the spacecraft had mated with its lunar lander.

As they boarded the aircraft carrier USS *Hornet*, the three astronauts wearing isolation garments—which included a hood, mask, and respirator—actually looked like creatures from another world. For the next three weeks they would be quarantined in a controversial attempt to keep the world safe from lunar organisms.

In the years preceding the moon landing, scientists had engaged in passionate debate about what the first lunar explorers might find. Some feared that

the spacecraft and astronauts would sink into the lunar surface and be lost forever. Others theorized that lunar dust would burst into flame when exposed to oxygen. By far the most heated debate revolved around the potential contamination of Earth by lunar organisms. As early as 1962 a report for the Space Science Board of the National Academy of Sciences noted that "the introduction into the Earth's biosphere of destructive alien organisms could be a disaster...."

"What you have to bear in mind is our extreme ignorance about other bodies in space in the decade of the 60s," says Carl Sagan, who was involved in the contamination debate as a young astronomer at Cornell University. "We were really ignorant of the moon's past history. There were some suggestions that there was a time when large quantities of organic molecules built up on the moon. There were other suggestions—verging on the limits of scientific unrespectability—that said there were ancient lunar oceans."

Sagan, as well as the vast majority of the scientific community, considered it highly unlikely that any organism could live in the hostile lunar environment. An article he wrote for the *Proceedings of the National Academy of Sciences* emphasized the extremely low probability of contamination, but Sagan nonetheless favored protective measures. By 1964 lunar contamination worries were serious enough to prompt the Space Science Board to form the Interagency Committee on Back Contamination, which consisted of experts from the Public Health Service, the Agriculture Department, the Fish and Wildlife Service, and the Army's biological warfare unit.

Among its many duties, the committee faced the task of designing contamination safeguards against the unknown. "Since it was impossible to know what a lunar germ was like, they decided to use as a model one of the nastiest earthly organisms known to man," remembers Charles A. Berry, NASA's director of medical research and operations at the Manned Spacecraft Center (now Johnson Space Center) in Houston. The scientists picked *Pasteurella pestis*—better known as bubonic plague.

Since the existence of lunar life could not be ruled out—and the risk of being wrong was the potential extermination of all life on Earth—the committee ruled in favor of temporarily quarantining people who had visited the moon. Congress authorized funds for NASA to construct a facility, known as the Lunar Receiving Laboratory, to isolate the returning astronauts.

Within moments of their arrival aboard the USS Hornet, *the Apollo 11 astronauts were whisked into quarantine (above). In an attempt to keep the world safe from lunar organisms, Neil Armstrong, Buzz Aldrin, and Michael Collins were kept isolated from the outside world—even from their wives—for nearly three weeks (left).*

PHOTOGRAPHS COURTESY NASA/JOHNSON

Many at NASA and elsewhere thought the quarantine was both unnecessary and unworkable. "There was lots of grumbling," remembers Sagan. "A planetary geologist at the University of Chicago, Ed Anders, volunteered to eat a sample from the moon to prove it was harmless. I answered, 'Fine, but he will have to eat it *on the moon*. It will be too late if he eats it down here. If he is wrong and gasps and dies, then whatever killed him is already among us.' "

It didn't help matters when a few months before the Apollo 11 launch, *The Andromeda Strain*, a novel written by a Harvard medical student named Michael Crichton, made the best seller lists. The book narrates how a virus from outer space nearly wipes out Earth's population. "The effect was horrible," remembers Berry. "It created all kinds of furor and generated thousands of letters which we had to answer."

Robert Gilruth, director of the Manned Spacecraft Center, assigned his special assistant, Richard Johnston, to manage operations at the Lunar Receiving Laboratory. "It was just another hoop we were going to have to go through if we wanted to go to the moon," says Johnston. One of his first jobs was to appease the contamination committee members. "We had to reestablish confidence with them," says Johnston. "There was a general feeling in the outside world that NASA just wasn't moving the way it should."

Johnston also succeeded in getting the NASA troops to accept the quarantine. In the meantime, skirmishes had broken out among various scientific teams associated with Apollo 11. The incompatible missions of all those involved—the biologists were trying to protect the world from lunar contamination, the geologists were trying to protect the lunar material from Earthly contamination, and the engineers were trying to get to the moon—resulted in considerable tension. In a defiant gesture, the biologists wore blue coveralls while the geologists wore green. Johnston scolded them: "How do you expect to work together if you can't even agree on the color of your uniforms?"

The most contentious battle was waged by the geologists, who argued that Earth needed no protection from the moon but that the lunar material had to be protected from Earthly contamination, which would destroy its scientific value. Health specialists wanted every container, building, and vehicle that housed or transported the astronauts or the lunar samples to have a reduced internal air pressure so that air would flow inward. The geologists wanted exactly the reverse—a positive internal pressure so that air would flow outward, away from the precious samples. What justified the lunar program, the geologists believed, was that specimens from another body in space would be brought back to help explain the origins of our solar system.

"The problem was that [the quaran-

From the Hornet, *the astronauts, still inside the trailer that served as the mobile quarantine facility, were flown to Houston, where they entered the Lunar Receiving Laboratory. The lunar samples arrived at the lab a short time later (right); even the capsule was quarantined (opposite). Concerns about otherworldly contamination had been intensified by the best-seller* The Andromeda Strain.

tine] was all show," says Gerald Wasserburg, John D. MacArthur professor of geology and geophysics at the California Institute of Technology, who is still fuming 25 years later. "It really didn't prevent contamination. The people from Fort Detrick [the Army's biological warfare facility], who really knew how to contain pathogens, thought it was ludicrous. It was all part of a fraud, but it couldn't be stopped because it was coming from such a high political level."

Increasingly worried that the geology was being sabotaged by the quarantine, Wasserburg wrote to President Nixon "to try to get this turned around." His letter did little to endear him to NASA. When they arrived at Houston prior to the Apollo 11 launch, the geologists found out just how low their stock had fallen. NASA had given their hotel rooms across the street from the Manned Spacecraft Center to reporters; the scientists found themselves in a motel some 15 miles away in Texas City. "We couldn't hold back," Wasserburg says today of the geologists' outspokenness. "We had to respect the scientific purpose of the mission."

As launch date approached, the astronauts were subjected to stringent isolation procedures. "If they caught something preflight," explains Berry, "we would spend forever trying to convince everybody [after the mission] that this was not some lunar organism." As a result, contact with the Apollo 11 crew was restricted to an absolute minimum for 21 days before the flight, and everyone on the access list, including family members, was medically monitored. This led to the embarrassing cancellation of a preflight dinner with President Nixon.

Amid all the tension among the scientific teams, a showdown was developing between NASA and the Interagency Committee on Back Contamination over how and when the astronauts should exit their spacecraft following splashdown. Contamination would still be a risk if the astronauts followed past recovery procedure and opened the capsule hatch while they were in the water. Immigration officers from the Public Health Service had even told

NASA officials that astronauts would not be allowed to enter the United States if they used the old recovery procedure. (In his book *Liftoff*, Apollo 11 astronaut Michael Collins speculates that he and his crew mates would have been condemned to ply the high seas in a rubber raft for the rest of their contaminated lives.)

The contamination committee wanted to keep the astronauts sealed inside the spacecraft until the capsule reached the *Hornet*'s deck and the astronauts could be transferred to a quarantine facility under strict conditions. This would involve either lifting the spacecraft by helicopter to the carrier, or having the carrier come alongside and winch the capsule up by crane. Both plans put the spacecraft, with the three astronauts inside, at the end of a cable high above the sea, a scenario NASA administrators found unacceptably risky. "The people who were proposing it had never been involved in a recovery operation at sea," says Christopher C. Kraft Jr., then director of flight operations at the Manned Spacecraft Center. "Would you really put a ship the size of a carrier alongside something which is bobbing in the water like a cork?"

Houston wouldn't budge, and the committee members felt the quarantine would be seriously undermined. With only 40 days remaining before Apollo 11 was scheduled for liftoff, they reluctantly agreed to the standard water recovery plan with the addition of new procedures to minimize the risk of contamination.

On July 20, 1969, Neil Armstrong finally set foot on the moon, where he reported that his boots sank "maybe an eighth of an inch." Armstrong and Buzz Aldrin spent two hours, 31 minutes, and 40 seconds on the lunar surface before blasting off to rendezvous with Collins in the command module. To minimize contamination, the astronauts vented the lunar dust from the capsule, and Armstrong and Aldrin vacuumed their suits.

Prior to reentry, mission control reminded the crew of the quarantine that awaited them. "I just want to remind you that the most difficult part of your mission is going to be after recovery," said Jim Lovell back in Houston.

"Keep the mice healthy," replied Collins, who knew that if the white mice in quarantine got sick, it would mean a longer stay in the facility.

The spacecraft splashed down before dawn. Those aboard the carrier could see a strobe light flashing as the capsule descended on three main parachutes. The recovery helicopter hovered until first light. Finally, the three astronauts, wearing their isolation garments, clambered out of the spacecraft into a rubber raft. They were raised in a small wire basket to the helicopter and ferried to the *Hornet*, which waited 12 miles away.

The Biological Isolation Garments had no ventilation and the visor tended to fog up. "By the time the chopper has deposited us on the hangar deck of the USS *Hornet* I am not only burning up but I can't see out of my fogged faceplate," Michael Collins later wrote about the arrival. "I can hear a brass band, and vaguely perceive a crowd of sailors off to my right."

Then the astronauts disappeared into a modified version of an Airstream travel trailer parked on the carrier's hangar deck. Waiting inside this mobile quarantine facility were William R. Carpentier, a physician, and John Hirasaki, a technician; both would remain in quarantine with the Apollo 11 crew.

After a shave and a shower ("the best shower of my life," wrote Aldrin), the astronauts changed into NASA flight-suits to meet President Nixon at a window at the rear of the trailer. "We had worked it out," remembers John Stonesifer, NASA's chief of recovery forces. "If the astronauts had gotten sick in the raft or on the deck—had to take off their masks or anything like that—I was to tell the bridge and the presidential party would be evacuated immediately."

When the *Hornet* arrived at Pearl Harbor, the mobile quarantine facility was transferred to a flatbed truck and carried to Hickam Air Force Base, where it was loaded aboard a C-141 cargo plane, flown to Ellington Air Force Base in Houston, then transferred to another truck and delivered to the Manned Spacecraft Center. The trailer was docked against an airtight hatch of the Lunar Receiving Laboratory, and the astronauts entered what would be their home for the next three weeks.

The laboratory's quarantine area was divided into a sample operations section for the moonrocks and a crew reception area for the astronauts and their support personnel, which included five laboratory technicians, three stewards, a clinical pathologist, a photography specialist, a logistic operations officer, and a NASA public affairs officer. A larg-

er area outside the quarantine housed the laboratories and offices of the mission geologists, biologists, botanists, and doctors.

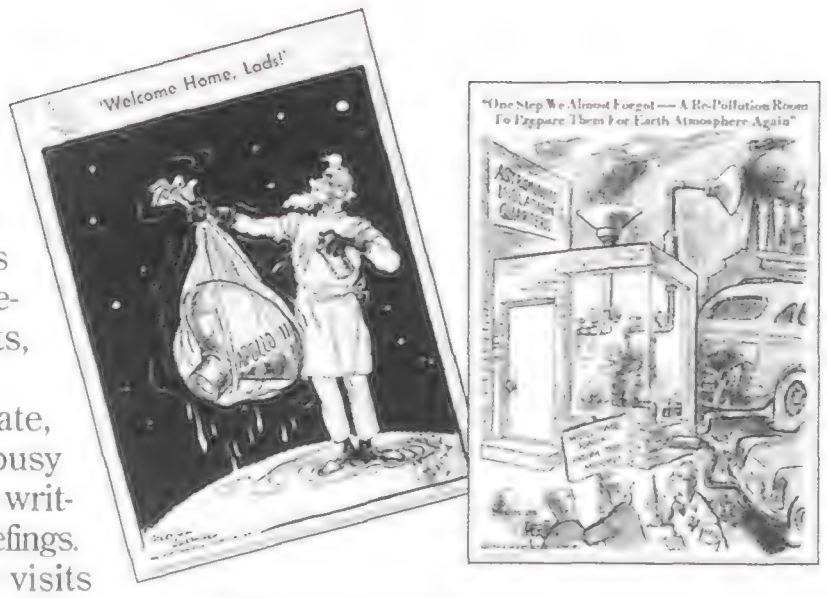
After a day off to recuperate, the Apollo 11 crew began a busy schedule of physical exams, writing the pilot's report, and debriefings. The debriefings, as well as visits with family members, took place through a glass wall. Food and other packages from the outside were delivered via an airlock.

"We were stuck in isolation," remembers Neil Armstrong, "but I never found it unpleasant. It wasn't its intended purpose, but the quarantine procedure turned out to be an advantage in our own personal situations. The [Lunar Receiving Laboratory] provided a service. Had we been turned loose to that avalanche of public interest it would have been impossible for us to go through the debriefing process or to help the upcoming crews. It allowed us to optimize the period right after the flight."

Armstrong celebrated his 39th birthday during the quarantine. While he ate birthday cake behind the glass barrier, his family and friends celebrated outside. "It was very festive...," says John McLeaish, a NASA public affairs officer. "We had champagne. We made no pretense of running a dry ship."

The lunar samples were also kept busy. The geologists studied the moonrocks with heavy gloves that extended inside handling chambers with negative pressure. The biologists fed lunar soil to a menagerie of laboratory animals, including a special batch of germ-free mice and Japanese pheasants. The botanists sprinkled lunar dust on plants to see if they died. (Since it had never been exposed to water, the dust had its elemental nutrients readily available and actually speeded plant growth, which turned out to be the only discernible effect the lunar material had on people, plants, or animals.)

Although the quarantine quarters offered an exercise room, Ping-Pong table, and television, life in the facility was becoming increasingly oppressive by the end of the first week, when the astronauts were asked to comment on post-mission operations. According to a



Within NASA and the scientific community, debate about the quarantine was intense. Political cartoonists offered their own views.

NASA history titled *Where No Man Has Gone Before*: "Armstrong was noncommittal, saying that so far it had been going 'about as well as you can expect.' Collins' less tolerant response was, 'I want out.' "

On August 10 the astronauts finally left the Lunar Receiving Laboratory. No one had found any evidence of infectious agents and the only people in the lab who still took lunar germs seriously were the building's janitorial crew. Robin Brett, who headed NASA's geochemistry branch, heard an account of a cockroach that crawled out of the Lunar Receiving Laboratory and then went back inside.

The geologists and a majority of NASA managers wanted to dispense with the quarantine permanently. The original recommendation of the National Academy of Sciences, however, stated that

the quarantine would remain in force for the first three missions. It was reasoned that a landing at a single location was not enough to rule out lifeforms on the moon.

In a sense, this proved true: In November 1969, Apollo 12 returned to Earth with *Streptococcus mitus*, a bacterium that had been discovered on a piece of the 1967 Surveyor 3 lunar lander the crew had brought back. The Lunar Receiving Laboratory later determined that the microorganism was from Earth, the result of someone sneezing on the Surveyor's TV camera prior to its launch. It had survived inside a foam insulation board for two and a half years. This experience convinced Apollo 12 commander Pete Conrad that contamination was at least a possibility and "probably the quarantine was a damn good idea."

Back on Earth, the astronauts were allowed to wear flightsuits and respirators during recovery operations, instead of the clumsy Biological Isolation Garments. Other minor changes made quarantine somewhat easier for the Apollo 12 crew to endure. "It wasn't onerous," says Conrad, who had arranged for a do-it-yourself Heathkit AM-FM receiver kit to be placed in quarantine with him. "It was a pleasant little interval. We got a lot of work done. It allowed us to do our debriefings in short order. Although by the end of it, we all wanted to get out."

Richard Gordon described his quarantine experience as "a welcome breather. Besides, we were pretty pampered. It was like living in a first class hotel."

The accommodations got crowded, however, when a technician's glove ripped and 11 scientists accidentally exposed to the lunar samples had to be confined to quarantine. (A similar incident had occurred during Apollo 11, which resulted in two extra inmates.) The newly incarcerated geologists didn't have much to do. "They used to stay up all night and drink and play poker and shout and holler," recalls Conrad. "It got so bad one night I had to go in and tell them to shut the hell up."

Still, for those already inside, the quality of life improved. "We got better wines with dinner and the level of conversation picked up," remembers NASA public affairs officer Douglas Ward.

The quarantine for the Apollo 12 crew

Mars and Contamination

"Mars is different," says Chris Kraft, former Johnson Space Center chief of flight operations, who fought unsuccessfully against the lunar quarantine. "We knew nothing could live on the moon, but there may be areas of Mars which could sustain life." Indeed, contamination is still very much an issue in discussions on the exploration of Mars, and the scientific community believes the implications are serious enough to warrant attention.

The major concern with forward contamination—the contamination of the Martian environment by terrestrial organisms—is that it would compromise the search for evidence of past or present life on the Red Planet. In 1992 a task group from the National Academy of Sciences urged that every attempt be made to obtain evidence of past or present life on Mars prior to manned missions, which will contaminate the planet. The group also recommended that landers (like Vikings 1 and 2) carrying life detection experiments should be sterilized.

While it's not likely that we will incur the risk of back contamination—the contamination of Earth from another body in space—from Mars anytime soon, the task group recommends educating the public to offset negative reactions, especially in the case of missions returning with samples. In addition to scientific concerns, their report acknowledges that this issue "is driven by many factors—societal, political, legal, ethical, and others...."

According to Carl Sagan, perhaps the salient question about Mars and contamination may be the same one that was raised 25 years ago about landing on the moon: "Where we are profoundly ignorant should we not err on the side of safety?"

was lifted 36 hours early after tests failed to find any symptoms of lunar contamination among the astronauts or the scientists. Another request to stop quarantining was rejected once again, this time on the grounds that the Apollo 14 crew was scheduled to perform deep core drilling. (The Apollo 13 crew avoided quarantine because an explosion aboard their spacecraft prevented them from landing on the moon.) "As long as there is to be an attempt to obtain a subsurface sample from a depth significantly greater than that from Apollo 11 and 12, I expect a quarantine for Apollo 14 to be instituted," ruled James W. Humphreys, Jr., NASA's director of space medicine at the Office of Manned Spaceflight in Washington. "If Apollo 14 returns a documented five-foot subsurface sample with no evidence of organics, I would consider quarantine unnecessary for any future flights."

The moonrocks were studied inside low-pressure handling chambers in the Lunar Receiving Laboratory (opposite). Neil Armstrong found that a ukulele helped pass the time in quarantine (below). While the astronauts often resented their incarceration, they welcomed the privacy.

So Alan Shepard, Ed Mitchell, and Stuart Roosa also ended up in quarantine, which they treated with barely concealed contempt. "It was just something else on the list," says Shepard. By Apollo 14, attendance at the daily press briefings at the lunar receiving lab had dropped off substantially. "I didn't even bother to go over," recalls AP correspondent Paul Recer. "I just checked by telephone. By that time they had forced rats and mice and guinea pigs to eat lunar material and never found a single organism. Nobody cared anymore. By that time we were only interested in rocks."

On February 27, 1971, when Shepard, Mitchell, and Roosa walked out of the Lunar Receiving Laboratory after 15 days, the quarantine was officially consigned to history. Not a single organism from the moon had been found. The lab was later redesigned, and today it consists of laboratories and offices for the medical sciences division at Johnson Space Center.

Many of those involved—astronauts, NASA engineers, and scientists—still hold their original view of the quarantine, both pro and con. "I figured it was basically a CYA [cover your ass] operation," says Apollo 12 command pilot Dick Gordon.

Gerald Wasserburg has not softened his stance on the protocol. "It kept dragging the real purpose of the lunar program off the track," he says. "It made me so angry because it meant that to meet a risk which I believed was unreal, we were risking the failure of the purpose of the mission itself."

Carl Sagan is still pro-quarantine. "Fortunately, there was nothing alive on the moon," he says. "Down to the depths we probed, it was dead as a doornail. But suppose the highly improbable had come to pass?"

A quarter of a century later, the quarantine and its $14 million price makes an easy target. Critics always doubted both its necessity and its effectiveness. Ultimately it was not even an absolute quarantine; NASA had ruled that it could be lifted immediately in a life-threatening emergency. Now only a footnote in the history of the moon race, the quarantine is a quaint reminder of our fear of the unknown.

The Delta Clipper could change forever the way we get into orbit. Or prove to be nothing more than a $60 million parlor trick.

SINGLE STAGE TO...WHERE?

by Preston Lerner

The Delta Clipper has flown. The Delta Clipper has landed. Now the future of the Delta Clipper is anybody's guess.

Envisioned as the precursor to the world's first reusable, single-stage-to-orbit (SSTO) rocket, the Delta Clipper seemed to have sprung from a Buck Rogers comic strip. In three flight tests last year, it took off like a rocket, hovered like a helicopter, flew horizontally without changing attitude or altitude, and then landed—landed!—just like it had been launched, easing onto a specially prepared pad in a tail-down position. It was a classic case of science imitating science fiction.

"My first thought, as it lifted off and started coming toward us, was this: We may have a hard time convincing people we didn't do this in a studio," says Bill Gaubatz, director and program manager of SSTO programs for McDonnell Douglas Aerospace, the Clipper's principal contractor. "It looked *exactly* like our computer simulations and our artists' animations. I mean, it was just a picture-perfect flight."

Gaubatz preaches the gospel of the DC-X—short for Delta Clipper-Experimental—with the zeal of a true believer. Noting that the rocket is cheap to operate, simple to fly, and easy to maintain, he sees it as a potential DC-3 of space. "This is the next big step we're going to take in the field of transportation," he says. "We've built waterways and railways and highways and airways. Now we have to build a spaceway to create a low-cost infrastructure so that people can travel to and from space on a routine basis. That's what it's all about—routine transportation. Space is just another frontier."

But according to the project's critics—and there are lots of them—McDonnell Douglas did nothing more than build a big model rocket with off-the-shelf parts to perform a clever-looking stunt. "I'd like to congratulate McDonnell Douglas for flying it, but I'm still at a loss for how you translate the database they've gathered to an operational vehicle," says Bill Piland, chief of the space systems division at NASA's Langley Research Center in Virginia. "For this country to build an affordable space transportation system, it's got to have some advanced technology. That's the bottom line no matter what they say about using existing technology. And doesn't it make more sense to develop that new technology than it does to build and fly a demonstration vehicle?"

As often happens, the technical issues have been clouded by politics. Last October the defense department's Ballistic Missile Defense Organization, the Clipper's patron, ran out of money for the flight test program. Then the following month, a House-Senate appropriations committee earmarked $40 million for development of a DC-X successor. It also directed the defense department's Advanced Research Projects Agency to take over the program, and ordered the agency to invite other contractors to bid on it. Still, there's no guarantee

Awaiting a flight test last year, the cone-shaped Delta Clipper provided an arresting bit of variety to the landscape of the White Sands Missile Range.

that McDonnell Douglas or any of its aerospace rivals will get the financial support needed to prove the SSTO concept conclusively. So with the Delta Clipper grounded, perhaps permanently, it's a good time to ask: Was it one small step for a few zealous men and women, or one giant leap for mankind?

Paul Klevatt is McDonnell Douglas' answer to Ross Perot. He's got the close-cropped hair, the military bearing, the I'm-coming-through strut. He's got the up-tempo, no-nonsense, take-charge manner. He's even got the disarming sense of humor. "I've been feeling the pressure," he says. "I used to be 18 feet four inches tall. Now I'm down to five foot seven." After a brief pause for laughter, he adds briskly, "I've got a tremendous staff. But in the end, I'm the one who makes the calls. That's my job—to make the final decisions."

Klevatt has spent his career working toward that responsibility. He's done just about everything from building wind tunnels to designing afterburners to putting satellites in space and men on the moon. But with all that experience, he still says of the Delta Clipper, "This is special because it's giving us a chance to do something that's never been done before." It's not just the "yeah, we're doing an important job making systems fly and launching vehicles and all that" routine, he says. "This is the kind of program that comes along once or twice—maybe—in a person's career."

ERIC SANDER (3)

Would you buy a used rocket from these men? The idea of a rocket that could be used over and over again makes some engineers skeptical, but Paul Klevatt (above), Bill Gaubatz (below), and Max Hunter (opposite) say their team is already halfway along the road to proving the concept.

Last year, before the program ran out of money, that sense of mission was clearly evident throughout the Delta Clipper offices in the huge McDonnell Douglas facility in Huntington Beach, California. "The guys around here are like kids in a sandbox," said rocketeer emeritus Max Hunter. "I've always argued that you could make engineers move fast if you gave them a chance. BMDO has given them a chance. That's why this program reminds me *precisely* of the old days. The younger guys thought they'd never get a chance to work on something like this. And the older guys thought they'd never have a chance to do it again."

Hunter is the biggest throwback of all, an engineer who started with the Nike missile in 1946 and continued on to Deltas, Thors, and all the way up to the Hubble Space Telescope. But he has always had a wild hair. Only four years after Sputnik was launched, Hunter was challenging conventional wisdom about expendable rockets by promoting his nuclear-powered Reusable Interplanetary Transport Approach. Later, he was a driving force behind the Lockheed Starclipper, which helped inspire the space shuttle. And by the mid-1980s he was "agitating the system," as he merrily puts it, for SSTO rockets.

Multi-stage rockets have always been the cornerstone of the launch business, and for good reason. It takes enormous amounts of thrust, and proportionate quantities of propellant, to launch objects into space. But once a rocket is hurtling along at a few thousand miles per hour and a few hundred thousand pounds of fuel have burned off, it needs far less thrust to reach the velocity necessary to escape Earth's gravity (it's the difference between a fully loaded Greyhound bus going from 0 to 60 mph and a motorcycle accelerating from 40 to 60). So engineers long ago began designing rockets with multiple "stages,"

or self-contained motors, that could be discarded during flight like empty cartons of Chinese takeout.

You don't have to be a rocket scientist to recognize the drawback of staging—that is, sacrificing large chunks of rockets on the altar of necessity. And it's easy to see the benefits of being able to use a launch vehicle over and over again. The problem is that today's rockets simply aren't efficient enough to enable SSTO operation (in technical terms, we can't achieve a high enough "mass fraction"—the ratio of a rocket's propellant weight to its gross weight).

Hunter realized he couldn't do much about the propulsion side of the equation. But he reasoned that revolutionary lightweight composites, prodigious advances in computer technology, and a host of new miniaturized components could all reduce vehicle weight. And if the craft could be made light enough, that would overcome the penalty of the weight of the fuel an SSTO craft would need for landing.

Hunter didn't win many converts within the rocket community, but he eventually found a receptive audience in the Strategic Defense Initiative Office, which was then developing the "Star Wars" space defense system. SDIO (now the Ballistic Missile Defense Organization, or BMDO) was looking for a low-cost launch system, and after funding a $12 million feasibility study, the agency decided that SSTO might fit the bill.

In August 1991, SDIO awarded McDonnell Douglas a two-year, $60 million contract to build the Spaceplane Experimental, a.k.a. SX-1. ("DC-X," though used universally, is actually McDonnell Douglas' internal designation.) The company had submitted a radical concept: a rocket that would not only take off vertically but would land the same way.

Why? The biggest reason was weight. By forgoing a space shuttle-like landing, the designers didn't have to worry about wings and wheels, both of which are excess baggage in space. This would minimize weight (and drag), which would enable the use of a smaller motor, minimizing weight further. The design had significant advantages: loading and unloading payloads would be easier, the equipment would be more accessible for maintenance, and of course, the ability to land virtually anywhere would give the rocket unprecedented flexibility.

Now the bad news: To begin with, nobody had ever landed a rocket vertically in Earth's atmosphere. Sure, NASA had managed several vertical landings on the moon, but that had been in a relatively benign environment with one-sixth Earth's gravity, no wind, no atmosphere to speak of, and minimal ground effect (how the air caught between the craft and the ground affects the craft's flight). Adding to the daunting avionics challenges the DC-X designers faced was a fancy high-angle-of-attack maneuver the rocket was eventually going to have to perform to get from a nose-down position, which would mimic its attitude upon reentering the atmosphere, to a nose-up landing configuration. Also, without wings, the Delta Clipper would have to depend entirely upon its engines in order to reach the ground safely. And if the engines malfunctioned...well, can *you* say "public relations nightmare"?

So was vertical landing the way to go? The DC-X crew took their baby to the storied desert launch site at the White Sands Missile Range in New Mexico to find out.

Sitting on its launch pad the day of its maiden flight last August, the DC-X bore no resemblance to the graceful, slender Deltas and Titans it was designed to supplant. Forty feet tall and 13 feet wide at the base—about one-third the size of the envisioned prototype—the vehicle looked like a Mercury capsule with a glandular problem, or one of the Coneheads immortalized on "Saturday Night Live." Fully loaded with liquid hydrogen and liquid oxygen, it weighed in at slightly more than 20 tons.

To rocket engineers, the DC-X was a relatively prosaic piece of work. Modifying off-the-shelf technology, such as the engines used in Atlas and Titan upper stages, the small engineering team had been able to move from Day One to first flight in just 18 months. The Clipper's guerrilla approach was evident in its version of mission control—a homely trailer that wouldn't have gotten a second glance on the interstate attached to a Peterbilt. By mid-afternoon it was fully staffed with a grand total of seven people. Thanks to the automated controls, the flight operations team consisted of three men.

As the countdown proceeded, the atmosphere was strangely calm. "The bullfighter probably worries about the bull the night before the fight, but he'd better not be worrying about it once he's in the ring," flight manager Pete Conrad said later.

Still boyish and enthusiastic at 63, Conrad is a veteran of Gemini 5, Gemini 11, Apollo 12 (in which he became

ROGER BESSMEYER/STARLIGHT

the third man to walk on the moon), and Skylab 2. After his 1,180 hours in space, the first flight of the DC-X didn't hold much terror for him. First of all, he'd simulated it too many times. Second, he was too busy watching the gauges. Third and most important, "I didn't have to sit up there on top of the thing." He chuckled. "This is a great way to flight test."

At 4:43 p.m., four Pratt & Whitney RL10A-5 engines fired, and everybody held their breath while the computer ran through its self-check program. After 3.5 seconds that felt like eternity, the RL10s throttled up to 80 percent power. The Delta Clipper didn't take off so much as pop aloft and levitate.

Once it had reached an altitude of 150 feet, it hovered briefly as the smoke from the launch eddied up around it. Then, in a demonstration of its ability to deviate modestly from a simple ballistic trajectory, the vehicle slowly "translated" sideways, like a chess piece being slid across the board by an unseen hand. "Tracking looks good," Conrad reported.

After translating 350 feet, the rocket came to a hover over its landing pad. Then the engines throttled back to 50 percent power and landing struts snaked out as the craft sank slowly on a fiery plume. Sixty seconds after liftoff, the DC-X had landed.

"We've got a touchdown," Conrad said, sounding clinical. But right beside him Paul Klevatt was yelling "All riiight!" Buck Rogers was riding again.

Resistance to the Delta Clipper, especially within the rocket community, has been fierce and deep-seated. But the way Max Hunter sees it, "You can always get a technical expert to say 'This is nonsense,' because if he was as smart as he thought he was, he would have thought of it himself. There's a whole fraternity of throwaway-rocket people out there. They're scared to death because all they see is the upheaval."

But it's not fair to claim that every critic is merely looking out for Num-

This montage details the DC-X's entire flight path, including its unprecedented sideways "translation."

ber One. "We want analytical data," says one NASA space program manager, who asked not to be identified. "We're eager to learn whether this concept works, but nobody's going to be convinced one way or the other by this program." First, he points out, the DC-X's engines aren't nearly powerful enough to get a vehicle to orbit. Second, the vehicle incorporates conventional structures that are far too heavy for SSTO flight. Third, the program doesn't address the safety of reusing lightweight cryogenic fuel tanks (the shuttle jettisons the tank that holds its super-cooled fuel). Fourth, it doesn't fully address the thermal protection the rocket will need to reenter the atmosphere. In sum, say the critics, because the DC-X wasn't designed to reach orbit or endure the stresses of reentry, much less carry a payload, it ends up proving very little about the SSTO concept.

Paul Klevatt says the program was designed to highlight the "traceability" of technology and operations from the DC-X to a true SSTO vehicle. Pointing to the software, avionics, vehicle reaction system, vertical landing, down-sized mission control, and quick flight turnarounds, he estimates that his team is 30 to 50 percent along the road leading to SSTO flight. "If you're talking about the concept of reusability, it's 40 to 50 percent," he says. "If it's the actual materials, it's more like 30 percent. If it's operability and supportability, it's considerably more—60 or 70 percent."

Most importantly, the DC-X demonstrated that a rocket—at least a suborbital one—can be designed to be operated as simply as an airplane. (Klevatt calls this "going from a man-rated rocket to an FAA-approved aircraft.") He foresees a day when a fleet of fully operational SSTO rockets is operated and maintained by a crew of 35—a far cry from the 1,700 that tend to the shuttle or the hundreds that work on the Titan. Peter D. Zimmerman, an arms control expert and visiting senior fellow at the Center for Strategic and International Studies, agrees: "I don't think crew size will scale proportionately [as designers move toward a full-size vehicle]," he says. "What the DC-X demonstrated conclusively is that we can reduce the marching army needed to support an operable system by an order of magnitude."

Well, it sounds good. And so do those bold claims that the operational vehicle will carry a 20,000-pound payload to low Earth orbit for less than $10 million. (By contrast, NASA conservatively prices a shuttle launch at $413 million, while a commercial Delta 2 launch costs $50 million.) But the DC-X has done no more to justify these numbers than a Cessna can demonstrate aircraft performance at supersonic speeds.

NASA's Bill Piland calls the DC-X a "cartoon design," by which he means that it looks good and sounds good, but it offers nothing concrete to support all its tantalizing promises. He says "immature" design is what has caused the price tag of the National Aerospace Plane to keep ballooning—it's presently 50 percent higher than original projections. Then there's the shuttle—though orbiting a payload with that vehicle was supposed to run $100 per pound, it ended up costing close to a hundred times that. "To say you're going to fly at low risk and high [safety] margins using existing technology for $6 million a flight—well, I'd *love* to see it," Piland says doubtfully.

BRETT LITTLEHALES

Serving as flight manager, former astronaut Pete Conrad (below) was happy to let the DC-X fly unmanned. But the operational vehicle the Clipper team envisions (right) will be able to carry a crew.

Will the program ever get the chance to satisfy the skeptics? The original plan anticipated a $300 million to $400 million investment to build and fly a bigger SX-2 by 1996 and a full-scale prototype as early as 2000. At present only the SX-2 funding has been appropriated, and that commitment is $20 million lower than the funding for the DC-X.

The Clipper's reception in Congress has been as mixed as its reception in the engineering community. "As far as I'm concerned, the DC-X is just a stunt," says one Congressional staffer who works on space issues.

On the other hand, Republican representative Dana Rohrabacher feels strongly that the Clipper program deserves support (his district happens to include McDonnell Douglas' Huntington Beach facility). Rohrabacher's legislative aide, Tim Kyger, explains his boss' position: "Some people complain that they didn't demonstrate enough. It was a $60 million program! If they'd had more money, they would have demonstrated more."

But maybe wholesale government support of the program would be a mixed blessing. Back in 1989, while he was "agitating the system," Max Hunter published a paper on the benefits of a reusable SSTO vehicle. "[I]t must *never*, repeat, *never* be described as *the next national space transportation program*," he wrote. "It must go off in the desert and do its thing, a program of frankly reckless risk and perhaps even an object of ridicule. If it is made a 'national program,' *forget it*. We are out to save the bureaucracy from itself, not help it feed on itself."


UNITED STATES

The James Gordon Bennett Race is the world's oldest aerial competition. And to take the prize you must be ...

Fierce to Win

NASM (2)

A rarefied air surrounds the Gordon Bennett race, reflected in the artwork on the 1922 program (above) and the stately lineup in Geneva 72 years ago (top). Today's competitors, like the Japanese entry in the 1993 race (right), employ state-of-the-art navigation equipment and lightweight structural materials, but the fundamentals of gas ballooning remain unchanged.

by Linda Shiner

Photographs by Chad Slattery

The crowd on this now dark, high plain in New Mexico started assembling five hours ago. On the Kodak Albuquerque Balloon Fiesta launch grounds, 20 gas balloons—35,000-cubic-foot spherical bags of helium—silently await their cues from the master of ceremonies. "From Sweden, Hans Akerstedt," the emcee announces, and the Swedish entry, towed by its ground crew, glides toward the illuminated launch platform.

When the balloon reaches the stage, an orchestra strikes up the Swedish national anthem. Under the spotlights, members of the Swedish ground crew remove the bags of sand that weigh down the balloon and step back. The spectators crane forward. As the orchestra plays, the balloon ascends. The exhilarated pilots wave at the crowd cheering them below. One of the pilots tosses out a short line that dangles from the bottom of the basket; it holds a strobe light, and soon the strobe is all that's visible of the balloon in the night sky.

For sheer spectacle, the launch of a James Gordon Bennett aeronautical cup is tough to beat. It delivers all the pomp and ceremony you'd expect from an international contest that started in Paris in 1906. The oldest and most dignified aeronautical competition in the world, the Gordon Bennett is a distance race for gas balloons, the aristocrats of sport ballooning. Gas balloons are far more expensive and stately than their loudly dressed hot-air cousins. Buying and equipping one is a $40,000 proposition. It costs another $3,000 to inflate it—less in Europe, where helium is unavailable and balloonists use the cheaper and lighter hydrogen.

Following the Swedes' departure, 18 variations on that theme, roughly five minutes apart, provide the next two hours' entertainment. Eleven countries are represented, some with the maximum of three entries. (The Canadians were grounded with a leaky balloon.) A strong cheer for the home team sends off the first U.S. pair to launch: Randy Woods of St. Louis, Missouri, and Gordon Boring of Commerce Township, Michigan. The Australians, as they leave the ground, douse their launch crew with water ballast. A Polish team does them one better, dousing the

Wilhelm Eimers (left) and copilot Bernd Landsmann flew one of three German entries and were high on the list of most likely to succeed in last year's race. Eimers, a dogged competitor, once lost a balloon in the North Sea trying to make it to Sweden.

Patience is a necessary virtue for gas balloonists: it can take five hours to inflate the envelope even when the weather cooperates (right).

crowd from a hundred feet up. German pilot Willy Eimers, a legend among balloonists, showers the launch area with paper-thin beer coasters. The German contingent in the crowd sings and stamps and applauds. U.S. pilot Mike Wallace, whose copilot is a National Guardsman, waves to the crowd on

his journey to the platform, shouting joyously, "It's great to be in America! It's gr-r-r-eat to be in America!"

They are in America because the 1992 Gordon Bennett cup was won by David Levin, an American, and as stipulated by the Fédération Aéronautique Internationale, the winner's national aero club gets to host the next race. In the 1992 race, Levin, a wiry New Jersey native transplanted to Colorado, had flown from Stuttgart, Germany, to a town in southeast Poland, achieving the best distance—598 miles. That is the simple aim of the Gordon Bennett: the pilot who flies the farthest wins. The prize—nothing so crass as cash—is a plaque and prestige.

Named for James Gordon Bennett, the renowned publisher of the *New York Herald* who sent Stanley to find Livingstone and who put up the first trophy and a cash prize to attract entrants, the race differs from other ballooning contests, which usually test navigation skills. It lasts "as long as you've got country to fly over and you've got courage to fly," says Australian pilot Peter Vizzard.

Vizzard and his fellow pilots object to the characterization of ballooning as a game of chance. "Expressions like 'being at the mercy of the wind' tend to upset balloonists because we're not totally at the mercy of the

wind," he says. "We have a choice."

It's a limited one: up or down. The lower atmosphere is like a layer cake, and winds vary in speed and direction in each layer, so the options multiply. If a balloon is at 3,000 feet heading east at 10 mph and the balloonist wants to go faster in a slightly different direction, chances are good that one of the layers above will oblige. "In general, the higher you go the faster you go," says Vizzard. To get higher, a balloonist tosses ballast over the side—usually sand, sometimes water. "Or your copilot," Vizzard suggests.

To descend, the balloonist releases a small amount of gas by pulling a cord attached to a valve in the top of the balloon. Since the gas is irreplaceable, racing pilots avoid pulling the cord. "Don't touch the valve. That's a cardinal rule in the Gordon Bennett," says Randy Woods.

There are two distinct types of competitors

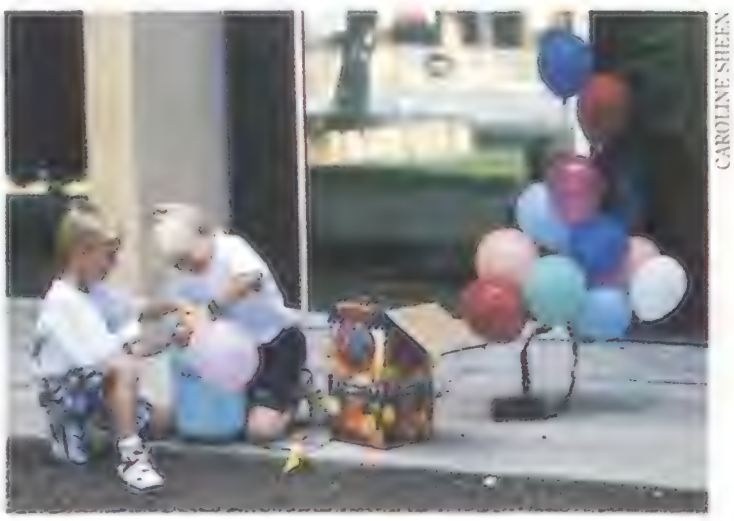
in this race, those Vizzard calls "gentleman balloonists" and those he calls "fierce to win." Woods is a solid representative of the first type. It is preposterous to think of him tossing water on his launch crew or indulging in any foolishness. A tall, wealthy sportsman with clean-cut Midwestern good looks, he enjoys the tactics of the contest mostly for what they add to the experience of the journey. Gas ballooning is unique in air travel. No machinery gets between nature and sensation; there is no engine whine, no intermittent roar from a propane torch, not even the wind rush that a glider pilot hears.

Gas balloons are the ultimate insiders, carried along in absolute silence within a current of wind. Passengers can hear the wind rustle branches if trees happen to be nearby, but unless the balloon is moving between air layers, where the wind changes direction, balloonists feel no trace of it.

"I was over east Texas, somewhere we might be on this trip," Woods says, "and we were at 16,000 feet, and I heard a screen door slam. I swear to God. And I looked down. It was a crystal clear night. The farmer had driven home, parked his car, and slammed the door.

"It's one of the great thrills. When you're up there at night and hear things, like a car driving over gravel. When you really get out in the country, you can hear the pumps from the oil wells. You just cannot describe to someone what it's like."

Good balloonists are nature's intimates. They have spent hundreds of hours—some of them, thousands—reacting to the behavior of the air, and they have the most refined sensitivity to weather on a small scale. The best of them can slip in and out of currents, choosing paths that carry them hundreds of miles, simply by tossing a little sand overboard to ascend.



CAROLINE SHEEN

Ballooning is often a family affair, with spouses and siblings pitching in as ground crew. Wilhelm Eimers' sons had their own collection of helium balloons.

Gas balloonists can never have too much sand—tossing it overboard enables them to ascend. Gordon Bennett competitors each carried about two dozen 35-pound bags of ballast that were filled on-site in blistering heat (left).

In stable conditions, small amounts of ballast will affect the balloon's buoyancy, and the pilot uses a metal scoop that holds a few handfuls of sand. Under turbulent conditions with strong downdrafts, balloonists will dump three or four 35-pound bags at a time. Under tenser conditions, sandwiches, empty oxygen containers, and pieces of equipment in increasing order of expense have been known to depart the gondola. "You're trying to balance the fact that the balloon cools at night and you must drop certain quantities of ballast to stay afloat," Vizzard explains. "Come the next day, the balloon reheats and re-climbs." The Gordon Bennett competitors each launched with between 22 and 29 bags of sand. They figure that will get them through three nights.

The winner will probably have to stay in

the air that long, and those competitors who have already proved their endurance seem the best bets. Besides Levin, last year's winner, one name stands out in the records of recent races: Austrian Josef Starkbaum, who won the title six years running, from 1985 to 1990. In 1991, 31-year-old German *wunderkind* Volker Kuinke took the cup from Starkbaum. Most gas balloonists start out in hot-air balloons, but the tall, baby-faced Kuinke has concentrated on gas ballooning, and by now he has made 275 ascensions.

Kuinke's countryman Wilhelm Eimers and Eimers' copilot Bernd Landsmann have two advantages over other teams. Both are small men, so they have a weight advantage. And they have Eimers, who flew 56 hours straight in a qualifying event for the Gordon Bennett. He will fly as long as it takes.

Polish champion Stefan Makne is perhaps the sentimental favorite. A dignified man with short silver hair, he won the 1983 race out of Paris, but due to strained relations between East and West, was unable to host the 1984 race from his native Poland. Should Makne win this year's cup, he could finally take the honor home.

"Some people here are flying in this event for the honor of being here," says Mike Wallace. "I mean, it's a tremendous honor to

CARL MEHLER

Ed Yost and Regula Hug (right), ballooning legends in their own time, reminisce in Taos, New Mexico, where Yost, who revived hot-air ballooning after World War II with his pioneering work for the military, has a workshop crammed with equipment.

Teamwork gets racers off the ground, as one ground crew demonstrated by monitoring their balloon's inflation.

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fly in this." He says he felt the same about participating in the race in Europe. "You kiddin'? To represent this country? A fat kid from Indian Orchard, Massachusetts? I woulda rowed all the way there." For heart alone, Wallace could be a contender.

But chance does play a part. And any of the 20 pilots who came to Albuquerque and anted up their $1,900 had a shot at making ballooning history.

The history of the Gordon Bennett race is a story of competitors who, as historian Tom Crouch writes in *The Eagle Aloft,* "overcome enormous obstacles in their pursuit of pure sport in the air." Gordon Bennett contenders have crossed the English Channel, the Great Lakes, the Alps, desolate stretches of northern U.S. and Canadian wilderness, and in 1912, a trouble spot on the Russian border where apparently tense Russians shot at one pair of pilots and imprisoned another.

Swiss pilots Theodor Schaeck and Emil Messner flew their balloon, the *Helvetia,* on what is probably the most harrowing journey in the race's history. They won the cup in 1908 and set a duration record of 73 hours on a desolate flight that carried them far out into the North Sea and across the Arctic Circle toward the Norwegian archipelago Spitsbergen. For two overcast days and nights they saw no land and no ships. "They lost hope," says Messner's daughter Regula Hug, a 75-year-old ballooning champion who was on hand for the Albuquerque race. "My father wrote a note that he thought would be found after their deaths. He signed it 'the victims of the *Helvetia.*' "

Hans Jörg Fröhlin, a Swiss copilot in this year's race who earned his license through Hug's instruction, picks up the story. Messner had to take the stiff collar from his shirt to write the note, he says, and penned, "We have done what we could do, but we have no luck."

"Then of course," says Fröhlin, who has a balloonist's appreciation for the irony of weather, "the luck came."

Miraculously, on the third morning the winds reversed, sending the pilots south toward the coast of Norway, where a ship captain caught one of their ropes and towed them ashore. But after facing death and—possibly worse—73 hours in the four- by five-foot gondola, the two men thought only of the competition.

"Poor Schaeck," says Hug. "He knew that if they got help, they would be disqualified from the race. He yelled to the captain to let go of the rope. He said it in French, in German, and in English. But the captain spoke only Norwegian." Over protests from the other pilots, a majority of the FAI judges voted to uphold Schaeck's victory. The challenge flew from Zurich the following year.

The pursuit of pure sport simply cannot overcome some obstacles. During the two

Josef Starkbaum (top, right) was a favorite, having won the race six years in a row. Last year, Ranier Rohsler (at left) copiloted. Racing gondolas are constructed of sturdy composites and weigh as little as 40 pounds (above).

Cass Foley readies Randy Woods' balloon for launch. As a chase crew driver, Foley will hit the road the morning after launch and, depending on Woods' luck with the wind, may drive for days.

world wars, the race was suspended. The competition might have slipped into oblivion had it not been for entrepreneur Tom Heinsheimer, who held his own Gordon Bennett races in California beginning in 1979. When the FAI reclaimed the event in 1983, the world had changed in ways that set up new hurdles, shifting but impassable.

"The big difference between this year and last year's Gordon Bennett—and all the last 10 Gordon Bennetts—is that we had political boundaries that we couldn't cross," says David Levin, the defending champion. "We had one Gordon Bennett where we took off from Salzburg [in Austria] and we couldn't land in Czechoslovakia and we couldn't get around it. So we landed in Austria. That was a very short Gordon Bennett." The winner flew 169 miles. "It was good for the chase [crews]," he adds. "They

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got to stop at a lot of restaurants."

The political situation in Europe was also good for six-time winner Josef Starkbaum. A pilot for Austrian Airlines, he won, he says, because he knew the territory. "The first races I won just by navigation," he says, "because they didn't have any global positioning system yet so it was VOR [aircraft navigation station] or astral navigation. I had an advantage in navigating. Now with the GPS, anybody can do it, so that advantage is gone."

Starkbaum has close-cut, steel-colored hair, steely eyes, and steel-rimmed glasses. His name in English would be "strong tree," and it suits him. The balloon he races is white and without decoration. Logos add weight. Starkbaum works hard to get rid of weight.

Starkbaum has a gondola made from a strong lightweight plastic, which he uses only for Gordon Bennett races. At about one-third the weight of a traditional wicker gondola, it offers more speed, which probably means more distance, but less protection.

The weight Starkbaum saves with his gondola buys him two bags of ballast. He also flies without a net. The net distributes the weight of the gondola evenly over the balloon envelope and was initially used because the varnished silk or muslin of early balloons was too fragile to support the basket on lines hanging directly from the envelope. Newer materials—rubberized cotton or neoprene-coated nylon—are stronger. Still, the net provides redundancy, and should the envelope puncture, the deflated balloon would be forced to the top of the net, act as a parachute, and arrest the descent. This insurance costs another 45 to 60 pounds, two more bags of ballast. Like Starkbaum, about half the competitors in the race were unwilling to pay that price.

"I know there are a lot of people in here wound up tighter than a two-dollar watch," Federal Aviation Administration official Dick Blondfield says at the briefing the day before the race. He is reminding the pilots to obey Federal Aviation Regulations and to stay below the race ceiling of 18,000 feet, but they are much more interested in the tracks and trajectories just provided in the weather briefing. Now that the predicted winds are beginning to seem real, the mood has grown more intense. The poolside terrace at the Albuquerque Hilton is packed with pilots and advisors bent over charts and discussing possibilities in a number of languages. Randy Woods studies the map, but he admits that trying to visualize the flight is futile.

"I've flown out of here twice, and in the back of my mind I think I know what's going to happen, but that never works, never works," he says. Like most of the pilots, Woods is hoping to stay at a low altitude the first night and ride north on the drainage winds that spill down the Sandia mountains. That way, he can avoid dumping ballast to cross the Sandias at night. "I'm gonna go up to Las Vegas [New Mexico] at low level. Up there I'm gonna start putting on a little altitude, and then we get in the prevailing westerlies, and two days later, we land in my back yard in St. Louis," he says.

Sweden's Hans Akerstedt, Jan Balkedal, and crew member Roland Moberg (center) talk strategy prior to the launch. Pilots admit that regardless of the amount of weather information, it's impossible to plan a flight that relies on capricious winds.

Distance fliers like Sabu Ichiyoshi are adept at grabbing naps whenever possible (top, left).

In truth, the only thing balloon pilots know with any certainty is the location of the launch site. They don't know how fast or how far they can go, and they certainly don't know where they'll land. "If you're sitting there happily going along at 20 knots and if you have the same altitude and the wind seems stable, everything's quiet, and you don't see any weather approaching, there's no reason to make any decisions," says Woods. "If suddenly you see another balloon going faster than you, *below* you, then you start making decisions."

The pilot radios his decisions to the chase crew, usually once an hour, and hopes the crew will be able to find him when it's time to land.

David Levin is the reason the 1993 Gordon Bennett was held in the United States. The Colorado-based balloonist won the race from Germany in 1992, and tradition stipulates that the winner's national aero club hosts the next race.

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By 7 a.m. the morning after launch, Woods' wife Fiona and chase crew driver Cass Foley, a 30-year-old caretaker of the Woods' properties in Aspen, Colorado, and the British Virgin Islands, were clocking 70 mph on Interstate 25 north out of Albuquerque. Some of the chase crews had lit out after the balloons the night before, but Woods' team decided to chase the balloon in the morning, since the winds were predicted to be slow and the day was likely to be long. Now Fiona was anxious to spot her husband's balloon with her binoculars.

She had already had one scare that morning. At breakfast one of the crew had spotted a gas balloon through a window of an International House of Pancakes. "It might be *the* gas balloon," said Fiona nervously as she went to the window. But it turned out to be Jacques Soukup from the U.S. Virgin Islands. He had the same slow winds that left other pilots close to the launch area, but some managed to find a way out of them. Soukup landed at the Albuquerque airport an hour after this sighting, six and a half miles from the launch platform—a new Gordon Bennett record, albeit for *lack* of distance.

"How depressing," Tomas Hora cried six or seven times. Hora, a German observer the race organization had assigned to Woods, was along to collect the balloon's sealed barograph at landing and to certify the landing location. He was young, opinionated, and obnoxious, and he had the maddening habit of radioing the three German challengers during the chase and speaking to them in German. But he also had an endearing, almost misty-eyed romance for the Gordon Bennett race. "Anybody who is competing in this race should be proud of himself because to be in a Gordon Bennett, you go into the balloonist history books," he stated with great conviction. "You sure do."

By 9 a.m. Fiona's crew had overtaken a flock of balloons and pulled off onto a side road to scan the sky for Woods' balloon, a big yellow ball with a red net. It was one of seven tiny dots sharing a vast blue sky with puffy clouds. The pack had flown all night to this spot some 75 miles northeast of Albuquerque, just south of Las Vegas. The first part of Woods' visualization had gone as planned.

At 10:15, the pilots radioed that they were fighting thermals, updrafts of sun-heated air that glider pilots love to find and distance balloonists love to avoid. (Gliders need thermals for lift; they orbit within them to gain altitude. Balloonists carry their lift with them and cannot exit a thermal at will.) At 11:15, after fighting the mix of updrafts and downdrafts, Woods and Boring were looking for a place to land.

The chase, which had headed into Las Vegas to wait for directions, now drove west to try to spot the balloon again. On a narrow road outside the town of Rociada, Swiss balloonmeister and chase crew member Rolf Goldschmidt located Woods and Boring with his binoculars. Four or five other balloons were in the vicinity, and as Goldschmidt

watched, a fine rain of sand streamed from Alan Fraenckel's balloon. Then another shower of sand. And another. And another. "Four bags," Goldschmidt said. "Fraenckel is fighting downdrafts too."

After the next radio message the chase drove on, trying to keep the pilots in sight and find the golf course that Woods had reported seeing. Foley ran into a gas station-post office called One Stop Rociada to get directions, then headed into the mountains on a gravelly switchback.

Woods' balloon, now easily spotted, disappeared behind a tree-covered ridge as the chase vehicle rounded the mountain. "My heart is slamming," said Fiona. It was impossible to tell whether the balloon would go down in the trees or make it to a small, treeless valley off to the left of the road. The road curved, and ahead, in the middle of the valley, four horses stood watching something just over the trees. The crew couldn't see the balloon, but the horses could.

Foley stopped the van and, pulling on his gloves, hailed three ranch hands who had been patching fences. And then the balloon appeared, so big and close it almost looked like the crew could reach up and grab it. Foley was explaining that the balloon was about to land and asking the ranch hands for help packing it up when Woods' voice came over the radio. "It looks like we won't be landing here after all," he said. "Uh, we probably won't be able to land the balloon until sunset." Sure enough, the balloon had

His flight got off to a promising start, but for Randy Woods, the experience of the journey takes precedence over winning a race. "On every distance flight you leave a little bit of your soul up there," he says.

In a balloon's-eye view of the crew and the New Mexico scrub, copilot Gordon Boring checks the global positioning system receiver to pinpoint the balloon's location.

begun to rise. "Heavy thermals!" said Foley. "Look at this!"

When the updrafts and downdrafts finally allowed the pilots to land about two hours later, they picked a lovely but less convenient spot tucked among the mesquite and piñon pines of a nearby ranch. It took the chase crew another hour to find the pilots. Though they looked tired as they walked down a steep ranch road to meet the van, the balloonists were smiling.

After the landing, Woods pitched in to help the people he had hired to help him, and though obviously disappointed with his distance, he was nevertheless gracious to the oblivious Hora, who pointed out that the Americans would be better competitors if only they would work together the way the Germans do. Woods heard him out patiently, standing in the pine forest next to the collapsed balloon, and agreed, "We really should do that."

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The Swedes and the Australians made the same choice. Eight other crews, including Stefan Makne and Mike Wallace, continued for a few hours but, having used so much ballast to keep from hitting the trees in the downdrafts, landed before nightfall. "I had 18 bags of ballast comin' into those mountains," Wallace said. "I landed with five."

Kuinke attempted the second night and landed at sunrise in Mosca, Colorado. Alan Fraenckel landed at sunset the second day, but he had made it all the way to Wood River, Nebraska. Austrian Thomas Lewetz just barely made it into the third day. He landed at 30 minutes after midnight in Whitman, Nebraska. And then there were two: Josef Starkbaum and Willy Eimers.

Like the pilots who made it to Nebraska, Starkbaum and Eimers found an eastbound wind at 3,000 to 5,000 feet during the second day. The pilots were able to wait for the second sunrise to heat the balloon to reach that altitude. Had they been forced to search for the current by bailing ballast, it's unlikely that either of them would have had enough left for the third night. Starkbaum had cut away five bags of ballast in the downdrafts over New Mexico when his variometer, which reports changes in altitude, reached 1,000 feet a minute in a descent. "We got clobbered," he said.

After 66 hours, Eimers landed in Buffalo, Minnesota, 968 miles from Albuquerque. Starkbaum's time was shorter, but he went farther. He flew 59.5 hours and landed 25 miles east of Lake Michigan in Campbellsport, Wisconsin: 1,138 miles for his seventh Gordon Bennett. This year's cup will fly from Austria.

For the chase crews, it's often a case of hurry up and wait (top). Swiss balloonmeister Rolf Goldschmidt and his wife Marie did just that outside Rociada while Woods and Boring fought downdrafts and updrafts and finally decided to land.

Woods' team calls it a day. After the balloon landed in a clearing ringed by pines and mesquite, much work remained. Woods, Boring, and observer Tomas Hora pinned down their position while Fiona Woods pondered packing up.

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At dinner that night in Santa Fe, Woods and Boring described the violence of the turbulence. They had been sucked up at 1,500 feet a minute and then slammed down at the same rate, over and over. On the way up, the basket spun like a tether ball, and the pilots hunkered down inside and held on to the rim. On the third trip down, ballasting like crazy, Boring had said, "I'm not going back up to 15,000 feet again." The consensus in the basket was to land.

Your Airbus is ready.

How an airline's inspection team checks out the newest addition to its fleet.

by William Triplett

Photographs by Gilles Bouquillon

When Peter Rottmann leans into the right engine of the brand-new Airbus A310 passenger jet, he doesn't like what he sees. "Eric!" he shouts above the roar of nearby taxiing aircraft. "What's this?"

Eric Mérel, customer liaison coordinator for Aerospatiale, the French partner in Airbus Industrie, hurries over and looks at the almost imperceptible discoloration Rottmann is pointing to on the inside wall of the intake. "Standard repair," says Mérel.

"Looks strange to me," says Rottmann.

"It's a patch," says Mérel. "Standard to fix a hole."

Fine, Rottmann says, so long as Mérel can *guarantee* that it's a legitimate repair, and not the mark of an untreated scrape. Mérel guarantees it.

Rottmann then points to some dampness evident on another part of the inside wall. "What's this?"

Mérel runs his finger in it, smells it. "Water."

"Think so?" asks Rottmann.

"*Oui.*"

"Eric!" This time it's Luis Cano, one of Rottmann's colleagues. He's under the belly of the airliner, pointing to a trap on an access door. "There's no way water can drain out of here," Cano says when Mérel arrives. Ice can form on the inside, which, he explains, can lead to its forming on the outside, affecting the flow of air around the jetliner.

Mérel, his smile and good humor still intact, says not to worry, that there's an internal drain that siphons off any water buildup. Cano, whose job it is to worry, presses for more details about the drain. Once he is satisfied, he continues his inspection down the belly of the aircraft, his nose about two inches from the surface. Every now and then he puts an orange sticker on the jet, makes a note in his black booklet, and moves on.

Standing on a ladder at the nose is David Ramirez, quietly busy with his inspection of the A310's radar equipment. Like his colleagues Rottmann and Cano, he is demonstrating the scrutiny that defines their roles as the three inspectors dispatched here to Toulouse, France, by Delta Airlines to make sure this $70 million aircraft works as advertised before the company takes possession of it.

In principle, Rottmann, Cano, and Ramirez are doing on behalf of their employer what home buyers do all the time: conducting a final inspection before settlement. Except this inspection will take three days. The details will be more numerous and complicated, as will the individual objects and items checked out. As flaws are identified, patience and nerves will be tried a little more. And the pressure, like the stakes, will be higher.

Beaucoup higher.

"If we accept the aircraft with a problem, then it becomes our problem," says Howard Mitchell, Delta's engineering and contracts representative in Toulouse. The jet comes with a three-year warranty, but repairs mean taking the jet out of service—costing money, angering passengers, and, ultimately, causing Delta officials in Atlanta to make unpleasant transoceanic phone calls. "If something goes wrong after the jet's in service," says Ramirez, "my boss wants to talk to me."

Airbus, of course, just wants to keep the customer satisfied—"That is the rule here," says Mérel—but the repairs and corrections increase Airbus' costs, particularly if a correction requires flying the jet to see if everything works okay.

Both buyer and seller realize that too many problems during this final phase are bad for everybody's business, which is why Delta keeps two inspectors per-

Above: From their perch on a cherry picker, Delta's Luis Cano (front) and an Aerospatiale mechanic examine the A310's tail surface. During the week-long inspection, the Delta team will keep the mechanics busy (right).

Hydraulic lift + hose = rain simulator. Inside the cockpit, inspectors check for leaks and test the windshield wipers.

manently stationed in Toulouse to help oversee aircraft construction from the beginning. The idea is to catch errors or miscalculations as they happen, so that any major rework can be done early on.

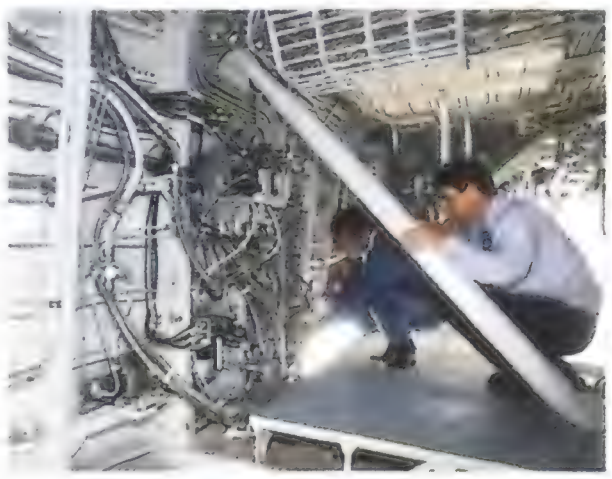
"By the time you get to delivery, the inspection is really just aesthetic," says Mitchell. But it is also the last time the buyer can ensure he's getting exactly what he wants. Hence, the inspectors carry 17 cards, each listing a dozen or more points to check, plus an inch-thick manual for systems and flight tests. By the time it's all over, the Delta team will have checked out between 600 and 700 items—with a team of Airbus personnel right at its side. Everyone shares the desire to be done in three days. But that isn't always possible, and it's never easy. "Delivery is the highest time of interaction," says Philippe Martin, contracts coordinator for Airbus. "There is a lot of tension and pressure."

Day One, a Monday, begins at 9:30 a.m. in a small briefing room at the Delivery Center, a narrow strip building surrounded by a parking ramp. Outside are several shiny new aircraft, all of which have recently rolled out of the Airbus final assembly hangar some 200 yards away. *Bonjours* exchanged, Mitchell, Ramirez, and Jean-Jacques Bernard, a flight test engineer for Airbus, review the technical logbook listing problems that Airbus has already detected and begun to fix. Business is supposed to be conducted in English, but occasionally Bernard consults his colleagues in a weird mix of French conversation and English technical terms—"*On parle du* air compressor"—leaving the Americans, who speak little French, somewhere between confused and annoyed.

The meeting adjourns and everyone heads outside, where, like a polished jewel, the product awaits inspection, its immaculate paint and metal brilliantly reflecting a gorgeous Toulouse sun. Aircraft serial number 676, Delta fleet number 038, the third of nine A310s the airline is buying, stands with every one of its doors, hatches, cowlings, flaps, and slats fully open or extended.

Rottmann, Ramirez, and Cano deploy to their starting points—wings, nose, and tail, respectively. Their tools are nothing more high-tech than a pocket flashlight, a screwdriver, and something that looks like an oversize dentist's mirror for peering into nooks. Waiting to

Delta's David Ramirez (left) and Aerospatiale's Eric Mérel peek inside the main landing gear bay (below); at right, Mérel inspects a flap.



elevate them on either a hydraulic platform or a cherry picker, as necessary, are three Aerospatiale mechanics in blue jumpsuits. Klaus Roggmann, ground acceptance engineer for Airbus, joins Eric Mérel as the three Delta inspectors go to work.

Ramirez, an energetic man always ready with a smile and a handshake,

trots up a ladder into the nosewheel well, where he spends half an hour checking wire connections and general appearances. Mostly he pulls on piping to see how secure it is. When he finds something not right—a "squawk"—he marks the area with a peel-off orange sticker for the mechanics who will later come fix the problem.

He clambers back down the ladder, then up into the forward cargo compartment, where he slips through a tight passageway at the front of the compartment that leads into the avionics bay. "There's a lavatory and galley right above," he says. "It's important to check for any water seepage" because all the cockpit circuitry is situated here. He pulls on more wires to test their anchoring. He looks for any chafed cables. He tugs at cotter keys to make sure they're secured. Then he eases himself back out to the cargo compartment, which he inspects for fire containment.

Rottmann, meanwhile, is on one knee as he rides atop the hydraulic platform at wing level; a man of quiet affability, he has collapsed and reconfigured his body so that he now looks like a human microscope focusing itself. He begins at the tip of the right wing and in five minutes has proceeded maybe an entire yard along the leading edge. Occasionally he peers underneath, his hand delicately placed on the upper surface of the slat, "like he is touching a woman," as one French observer says. It's an apt comparison, but when inspectors touch anybody they presumably are not, as Rottmann is, feeling for loose rivets.

After working his way along the entire length of the wing, Rottmann has the driver inch back out so that he can stand and survey the immediate forward area of the wing. Thirty minutes later he's inching along the trailing edge, staring hard at the flap assemblies and periodically reaching into the flap wells to test the security of the hosing and piping, which carry the hydraulic and electrical systems that operate the control surfaces.

An Airbus colleague calls to Mérel, who's peering over Rottmann's shoulder, to ask how it's going. Mérel kisses his fingertips as if to say "*Magnifique!*"

As for Cano, the expression on his face might make anyone think he is studying perhaps a piece of fine porcelain or examining a rare book. Actually he is some 50 feet in the air on the cherry picker, holding a wide-body jet by its tail. (His jolly face and Latino charm mask an occasionally wicked sense of humor: when inspecting jets at McDonnell Douglas, he will sometimes pull out a magnifying glass à la Sherlock Holmes "just to make them nervous," he says.) He is searching for anything, from paint bubbles to ill-fitting parts, that could disrupt airflow and create drag. "One or two things won't really make a difference," he says. "But they start to add up and before you know it, your fuel costs are going up."

A control surface on the left horizontal stabilizer doesn't lie flat and snug, one of its corners rising maybe a couple of millimeters. Cano squawks it with a sticker. "They'll replace it with one that fits better," he says.

Lunchtime approaches, and everyone breaks for the national rite that essentially shuts down all of France from noon to 1:30 p.m. The Americans, for whom lunch is often caught on the run, if at all, politely grouse about how it would be nice to keep working, but this item is non-negotiable. By 1:45 work resumes with Rottmann scrutinizing the left wing as he did the right; he then examines the engines. Cano finishes the tail assembly, then alights from the cherry picker to check the underbelly. Ramirez becomes a tunnel rat of sorts, crawling up into the main gear wells and then disappearing through an access panel into the compartment housing the air conditioning units.

For the rest of the afternoon the inspectors climb, pick, and fret over every square millimeter of the aircraft's exterior. By day's end the A310 looks as if it has several localized outbreaks of measles, the orange stickers tending to cluster along the leading and trailing edges of the wings as well as on parts of the underbelly and tail sections. Back in the briefing room the Delta team tallies up its squawk count (less than 50, which they say is not bad) as Jean-Jacques Bernard takes notes. Most of the squawks are minor, except for hydraulic leaks in the left strut well and a flap actuator.

Bernard says the mechanics are on duty until midnight. They'll get to it right away.

The feeling is palpable throughout the room: If the next two days go like today, everything will be completed right on schedule.

"You can separate the customers by the category of their concerns," says Mérel. "Americans are very technical. They want to know about the engines, the performance, the hydraulics. They are not really interested in cos-

metics. The Middle Eastern carriers are technical too, but they are more sensitive to paint. They want the aircraft to look good in the airport and they're also worried about paint peeling, because once it starts [the entire livery] must be redone."

No matter how big or small the concern, Mérel says, Airbus will do what it takes to keep the client happy. Which isn't to say, however, that the concept of customer service is without limits—a point that begins to emerge on Day Two (interior inspections) like a growing pain in the *derrière*.

Ramirez and Rottmann are joined in the cockpit by Jon Williams, a Delta pilot who is fleet manager for the A310. First order of business is to check avionics. Ramirez takes the left seat, Rottmann the right, Williams the flight engineer's rear middle seat. Williams holds the test manual on his lap and works his way down the checklist on each page as Ramirez and Rottmann press various buttons. Klaus Roggmann of Airbus stands and observes.

"Light should go out, no configuration change," Williams says.

"Right," says Rottmann.

"Light should come back on," says Williams. "We should get alarm."

"Right," says Ramirez, who is then drowned out by a computerized voice blaring "Windshear! Windshear!"

They spend the entire morning like this, calling back and forth to each other, confirming which lights and gauges are reacting or not reacting as they should, examining everything from the performance of sophisticated electronics to the comfort of the seats.

Cano, meanwhile, roams the cabin and galley areas, his sheet of squawk stickers in hand. The whole interior of the jet smells and, to some extent, looks like a new car, complete with clear plastic over the carpeting. He checks the fit of every galley door, the seal around the edges of the galley floor, the alignment of each overhead storage bin and how smoothly it opens and closes. He is just finishing up his inspection of the lavatories when the requisite break for lunch is called.

So far, so good, but the Delta team still needs to run up the engines. After lunch, Cano steps into the cockpit and takes the left seat, successfully ignites both engines, then taxis the jetliner to the test area. First check: brakes. Cano locks them up as he throttles to just shy of takeoff power. The airliner rocks in place, with about 100,000 pounds of thrust trying to hurtle it forward. The brakes work fine, but a brake indicator on the control panel doesn't. Later tests reveal some crossed wiring, override-

In the cockpit, the Delta team tests the avionics, hydraulics, and fuel system (top). Because activating a hydraulic system could seriously injure any mechanics repairing it, labels are posted in the cockpit to warn that work is under way.

switch failures, incorrect readouts on a fuel level indicator, and a pack (climate control unit) failure.

"None of them prevents us from doing the test flight tomorrow," says Williams as everyone assembles back in the briefing room, "but we'd have to fly again after the repairs to verify things work. So it's smarter to let them fix everything first, then fly just once."

A second flight had been the subject

of dispute when Delta took delivery of its first A310 some five months earlier. According to Williams, that aircraft also had pack problems (as do many jetliners of all makes and models), "but Airbus said they could check it out on the ground. We got together and decided we wanted to fly again, and that was that. Airbus sort of got on their high horse because it costs them money to fly, but they backed off."

Philippe Martin of Airbus says it was a matter of following the rule book. "It was just Airbus policy that you don't have to fly again to check it," he explains. "But this was the first aircraft for Delta and they were not used to our standards, so Airbus decided to keep the customer happy."

At present, the customer is about to become unhappy. Jean-Jacques Bernard says some of the reading and indicator failures were very likely the result of the Delta team's not having cleared and reset a computer memory prior to the run-up. His implication, cordially put, is that they didn't run the test properly. (The Delta inspectors can't remember whether they had reset the computer memory, but it becomes something of a moot point after the discovery of faulty hardware.) The rest of the items will be repaired or replaced as necessary during the evening shift, says Bernard.

During the debriefing after the first test flight, Jean-Jacques Bernard (center) assures Delta that all repairs will be made before a second test flight.

Mitchell, Williams, Ramirez, Cano, and Rottmann step out into the hall for a moment. "It's a little like a football game," Williams says in an aside. "You play, then get together, strategize, go back and play again." They're not buying the computer memory explanation and need to decide how to deal with it. Mitchell leads the group back in and says, "How will you verify that all the fixes have been done before we do the test flight tomorrow?" Before anyone can answer, Mitchell says his people want to do another engine run-up tomorrow prior to the actual flight.

Agreed.

Day Three dawns spectacularly under glorious sunshine and cloudless skies—the perfect day to put a 180,000-pound wide-body jet into a stall, or lose one of its engines on takeoff, or abort its takeoff, or try to land it at dangerous airspeeds. The Delta team is anxious to get airborne: the jet could be on its way to Atlanta tomorrow if everything checks out. Nothing would please Airbus more, but tensions return when Bernard announces at the morning preflight briefing that the mechanics weren't able to correct everything last night and will need at least another couple of hours.

Mitchell wishes he could be sure this means only a slight delay. "But I have a hard time telling whether [they] are telling it to me straight or blowing smoke up my ass," he says. "I have no idea when we'll fly."

The team decides to spend the extra time inspecting the aircraft further. The inspectors fan out among the Aerospatiale mechanics, who are busy installing a new valve on the troublesome pack unit and replacing a sensor in the right wing flap assembly, which is believed to have caused a faulty reading yesterday in the aircraft's central electronic monitor.

Cano is on the platform re-scrutinizing some of the tail surfaces. Below, two Aerospatiale mechanics complain in French that if the Delta guys keep picking over the airplane, they won't be taking the jet home today, tomorrow, or the next day.

Morning becomes lunch becomes late afternoon before Bernard finally says it's okay to fly. Jon Williams takes the left seat; in the right is Airbus' number-one test pilot, Pierre Baud, a former military test pilot who has flown over 300 types of aircraft. Taking the flight engineer's seat is Peter Rottmann, who has spread the flight test manual across his lap.

Airbus has already flown the jet four times and has secured an airworthiness certificate from France's aviation authorities. The customer's test flight is basically to verify that what has been checked on the ground does indeed perform in the air. "The flight is essentially systems-oriented, to see how they all work in flight," says Baud. The stall and the unsafe-airspeed tests are flown, he says, to see if the resulting emergencies develop in the manner the flight manual describes. If they don't, it could mean a problem with the airframe rigging.

Takeoff goes exactly by the book. But as the jet climbs through 500 feet a piercing whistle tears through the cockpit. "Air leak," Williams says, indicating the cockpit glass; not a showstopper though. Williams turns east to line up with a vector that will take the aircraft along the Riviera and out over the Mediterranean. Eventually he levels out at 41,000 feet, where one of the first tests reveals that a high-frequency radio isn't working. There's also a discrepancy between two systems that show wind readings.

Williams executes the first systems check by shutting down the generators to see if the auxiliary power unit will kick in to cover. It does; Williams is im-

pressed. "We didn't even lose the autopilot!" he says. (Baud, for whom all this is routine, is busy pointing out the cities of Nice and Cannes below.)

Next is the depressurizing check. Williams shuts off cabin air pressure, which is normally maintained at around 6,000 feet above sea level. The reading on the cockpit gauge starts to rise. "We should get a warning light at 10,000 feet," says Rottmann. They do. "Oxygen boxes should drop at 14,000," he says. They do.

"Great!" says Baud, who now shares his co-pilot's excitement about the flight. "Shall we shut down some engines now?" Williams descends to 35,000 feet and alternately shuts down and then relights each engine; no trouble develops. The real fun, however, begins as Williams noses the jet over into a rapid descent—bringing the ground into disturbingly clear view—to trigger the alarms for an unsafe descent. He levels out at 20,000 feet, then disables each hydraulic system in turn to see how the A310 flies without them. "Flies great," he says.

"Excellent," says Baud. "Are we ready to stall now, Captain Jon?"

Williams idles both engines as he pulls the nose up about 15 degrees. Airspeed begins to drop, from 178 knots to 148...140...132...120.... "Stick shaker?" Rottmann asks, referring to the stall warning system, which the manual says ought to go off about now. It does—loudly. Then the stall hits: the entire jet shudders and shakes violently, with the floor seeming to give way as the aircraft begins to plummet. It's a stomach-turning feeling, alleviated only slightly when Williams throttles up and noses over to resume normal flight.

"Very good, Captain Jon!" cries Baud. "Let's do it again!" After two more stalls they descend to land and drop the wheels, but on final approach Baud retracts the wheels, then tries dropping them again. A computer voice shouts "TOO LOW GEAR! TOO LOW GEAR!" and prevents the deployment—there is not enough altitude left between the aircraft and the runway. Williams calmly powers up, goes around, then shoots his landing. He throttles back, then throttles up to take off again. As the rear wheels leave the concrete Baud throttles back the left engine. "We have lost number one, Captain Jon!" he yells. The jet begins an awful yaw to the left with the ground racing by barely 150 feet below, creating the distinct impression the aircraft will never make it to 200 feet. Suddenly the autopilot kicks in, pushing the rudder hard to the right to compensate for the yaw. It's as if a giant hand grabs the tail section and jerks the jet back onto a straight course.

Several more unsafe landing approaches and a perfectly aborted takeoff later, the jet is back on the ground. In addition to the problems noted ear-

Cano (standing) and Ramirez and Roggmann (kneeling) check out the A310's cabin, which won't be fitted with seats until after it arrives at Delta headquarters in Atlanta.

Delta pilot Jon Williams (left seat) and Airbus test pilot Pierre Baud put the A310 through its paces during the initial test flight.

Drag is in the details, so Cano makes sure that all control surfaces lie perfectly flat.

lier, the right pack unit failed once again, as did one of the fuel pumps.

Prior to the debriefings, the Delta team gathers together to discuss how to proceed. "I don't like what we've been finding," says Mitchell. "And I don't like how they always try to explain things away. I want to re-fly and I think we should use the [cockpit] air leak as the reason."

But when Delta requests a re-fly during the debriefing, Airbus raises no objection. Then, just as things seem to be going smoothly, Williams takes issue with Bernard's theory about the fuel system failure, which is that Baud switched the pumps off while still in flight. "It's possible that caused it," Williams says, "but the computer [controlling the pumps] may be the problem too." The suggestion is clear: replace the computer. Which, after some consultation in French with his colleagues, Bernard agrees to do. Repairs will go on until midnight, then resume in the morning, with everyone set to meet again at 11:00 a.m. for the preflight briefing.

But at 9:00 a.m. on Day Four it's clear the repairs will require another 24 hours. Then at 9:00 a.m. on Day Five, Friday, Bernard tells Mitchell that the seal around the cockpit glass is going to take yet another 24 hours to cure. One day's delay, even two, wouldn't be so bad. But a frustrated Mitchell knows Airbus mechanics do not work over the weekend (union contracts prevent it), meaning the earliest re-fly will be Monday. Based on the normal delivery schedule, Delta had slated the jet to enter service two days ago; every day it is not in service means lost revenue. Mitchell simply tells Bernard he will be in his office on Saturday, where Bernard can reach him immediately if any other problems develop.

"If there are more problems I won't tell you," Bernard says, "because you'll kill me." Mitchell simply smiles and says nothing.

Everyone on the Delta team has worked enough deliveries to know that the squawks and failures turned up so far haven't been at all unusual. In fact, Ramirez says he has generally found more squawks on aircraft built by U.S. manufacturers. And the team has absolutely nothing but praise for the quality of Airbus technology.

The trouble here is, to a small extent, the simple desire on the part of both buyer and seller to finish the deal. "Everyone's exasperated by now," says Mitchell, who gets no dispute from Airbus. The previous two aircraft went through delivery with far fewer hitches. To a greater extent, though, the trouble is the result of different cultures with different ideas about whose opinion is most important in a business deal. More than one Delta official says that Airbus indeed wants to keep the customer happy—on Airbus' terms. "They're

The A310's delivery to Delta was low-key, but when Air Canada picked up its first airliner, Airbus dressed the jet appropriately.

very conscientious about their product, but they take great offense if you find anything wrong," says Williams. "They can't conceive that you'd want something another way, that you'd question something." The feeling Delta is getting from Airbus is that this could have already been a done deal if Delta would stop being so picky.

When it is noted that Delta has gotten its way on virtually everything to date, Mitchell acknowledges the point but questions why he's had to be so insistent at times. "When we tell Boeing or Douglas we'd like something different, they say okay and try to work things out. Airbus says *Why?*" The upshot is an aggressive customer who must be prepared to explain and defend almost every request.

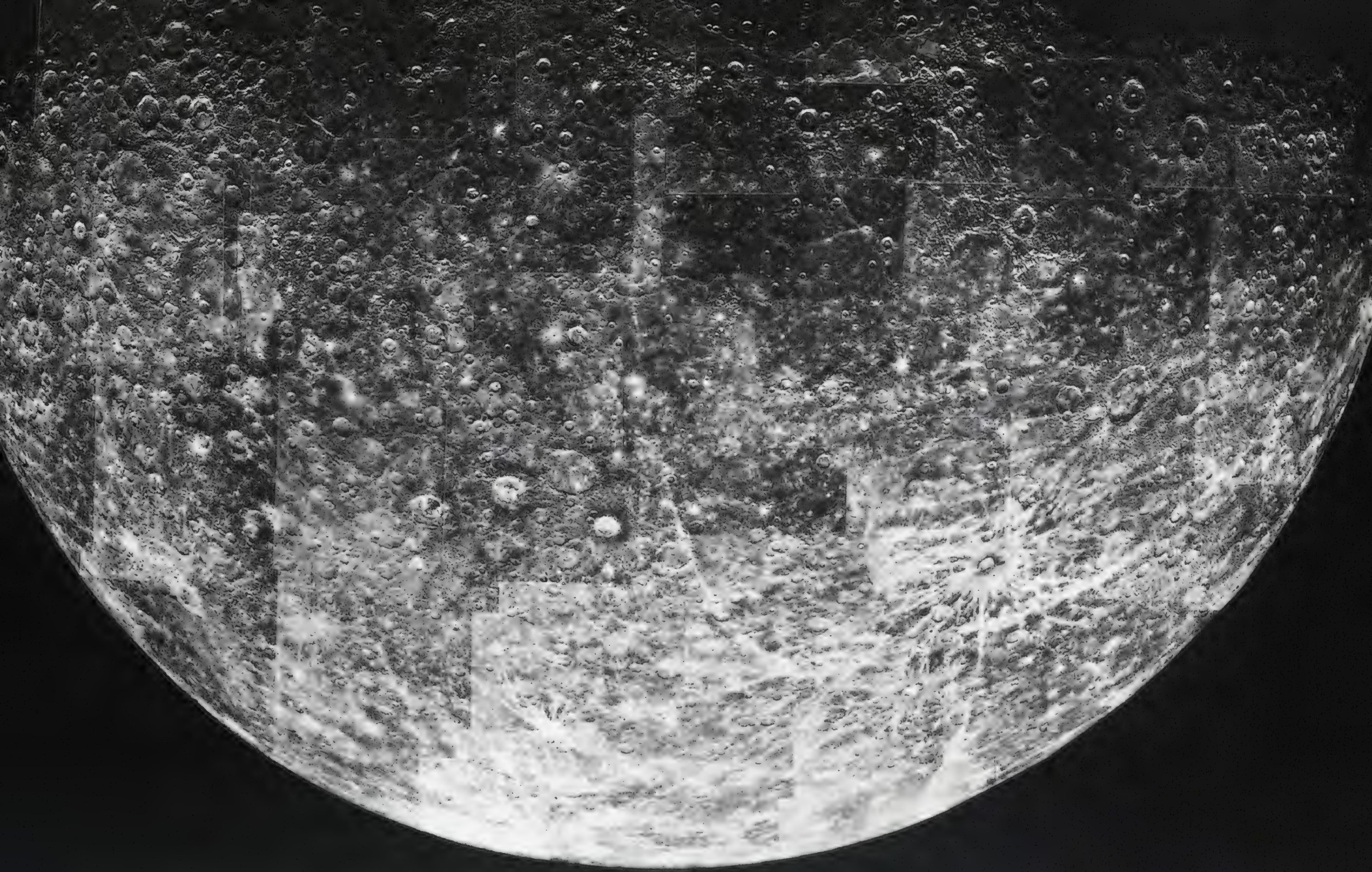
Alain Dupiech, a press officer for Airbus, says that American manufacturers are of course going to give special treatment to a major American carrier that regularly buys American-made aircraft (Delta has no plans for future orders from Airbus at the moment). Moreover, Dupiech says, the American idea of customer service "is sort of a brand-new thing for Europeans. You have to give it a little time. [Mitchell] has been trained on the Boeing system, so it may be a little unfair to compare us with them."

Day Eight arrives with clearance to re-fly. Bernard assures Mitchell that everything has been fixed except the high-frequency radio, which will be taken care of later. As Williams throttles up for takeoff, the cockpit seems to be pressurized with unspoken apprehension—Is everything really working? Is anything else going to fail?

The climb to altitude is notable only in that no whistling is heard, indicating the cockpit glass has been sealed. The contradictory wind readings have been resolved as a software problem, and the fuel pumps are doing their job just fine. Everything goes swimmingly, in fact, until final approach, when the right pack fails again, causing a streak of swearing in both English and French. Williams, who was supposed to have been home three days ago, asks for a knife so he can cut his throat.

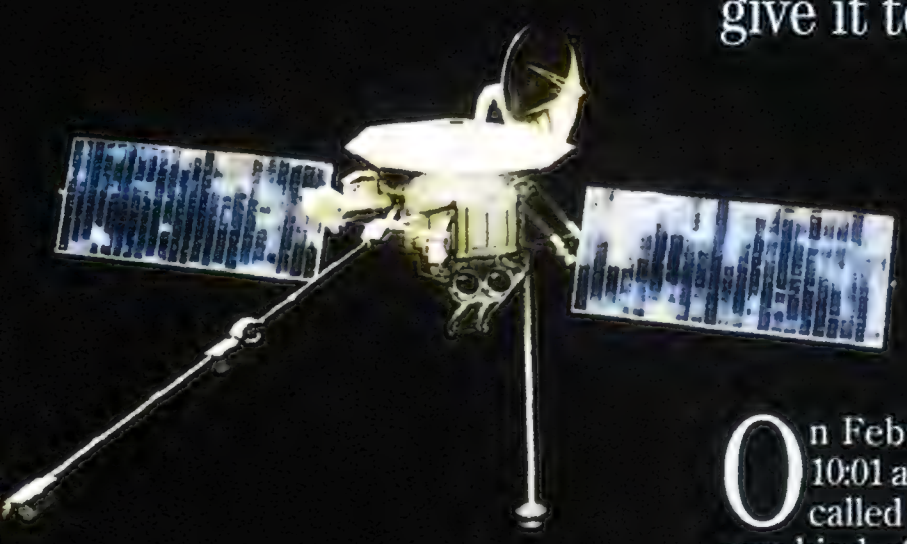
But the pack problem is not serious; once a faulty thermostat is replaced, the jet is officially accepted. The only formality left is the supremely anticlimactic transfer of title and funds, which occurs in the form of a four-way conference call two nights later. Mitchell and his counterpart from Airbus are on one line in Toulouse, Delta officials are on a line in Atlanta, their financing representatives on another line in New York, and legal counsel for Delta on a fourth at the Federal Aviation Administration office in Oklahoma. Various documents are signed and pledges made, constituting the sale. Delta's attorney in Oklahoma then faxes Toulouse a temporary U.S. registration certificate for the A310.

After purchasing a new aircraft, some airlines celebrate with a splashy reception or a formal ceremony. But for Delta's Mitchell, a simple handshake with his Airbus counterpart will do. Then each goes home, doubtlessly looking forward to next month, when another Delta A310 rolls off the assembly line ready for inspection.



Gravity's Overdrive

Michael Minovitch wants the credit for finding a key that helped open up the solar system. Not everyone is willing to give it to him.



by Tony Reichhardt

Mariner 10 traveled to Mercury by using Venus' gravity to bend its course in toward the sun, a correction that would have otherwise required vast amounts of rocket fuel. The only spacecraft to visit our solar system's innermost planet, the tiny probe transmitted many detailed photographs of Mercury's cratered surface.

On February 5, 1974, at exactly 10:01 a.m. Pacific time, a tiny probe called Mariner 10 introduced a new kind of magic to the space program. The last in NASA's original line of planetary robots, it zipped past Venus with the speed of a bullet, then used the planet's gravity to swing itself around on a new course toward Mercury. For the first time, a spacecraft bound for another world changed course not with rocket fuel but by using a planet's gravitational field.

That simple, elegant maneuver stands, along with the development of the rocket engine, as one of the keys that opened the solar system to exploration. The Pioneer, Voyager, and Galileo missions all used gravity assists, and in fact would not have been possible otherwise. Without a boost from Jupiter, the Voyagers would have needed more than three million pounds of fuel to continue on to Saturn. As it was, they used about 11 pounds. Gravity assist is the most efficient form of space propulsion known.

The man whom many agree deserves the most credit for pointing this out did not share in the celebration at NASA's Jet Propulsion Laboratory in Pasadena, California, when Mariner 10 flew past Venus. He was embroiled in a bitter dispute with the lab over who should get credit for inventing the gravity assist technique.

The arguments aren't over yet.

In June 1961, only a month after Alan Shepard became the first American in space, a shy, intense 26-year-old graduate student named Michael Minovitch showed up to work as a summer employee at JPL. Growing up in Los Angeles in the 1950s, Minovitch had been the kind of kid who literally slept with his math books. "I wasn't a Romeo, I wasn't a car buff," he recalls today. "I tried to run my life as a person truly devoted to science." Minovitch was finishing his third year of graduate math and physics studies at the University of California at Los Angeles, working toward a Ph.D. He had spent the previous summer at Linus Pauling's lab at the California Institute of Technology, working on X-ray diffraction of crystals, but when he learned about jobs at JPL, he turned down a second summer at Pauling's lab to go to the place where the U.S. planetary program was being born.

The first successful U.S. planetary

MERCURY COURTESY NASA/JPL; MARINER 10 COURTESY JPL

CHAD SLATTERY (2)

Michael Minovitch (right) first began looking into gravity-assisted trajectories as a summer intern at JPL in 1961. He says Victor Clarke (below), then his boss, was initially skeptical of the idea. "Hogwash," responds Clarke.

mission, Mariner 2, was still a year away from its launch to Venus. At the time, there had been a few papers delivered at aerospace conferences about "multi-planet transfers" that could reach more than one planet with a single launch, but no one was spending much time worrying about *that*. "In the spring of 1961 the space program was challenged by just getting a goddamn spacecraft to last three months to get to another planet," remembers Roger Bourke, who later became Minovitch's boss at JPL.

If few people were thinking about multi-planet flybys, no one was pushing the idea that gravity could be used as a form of free propulsion. However, the principle was nothing new. Astronomers had known for centuries that comets can gain or lose energy when they pass near a massive body like Jupiter—energy exchanged with the planet's own orbital energy as it circles the sun. In the 1920s, the Russian theoretician Fridrikh Tsander pointed out that a spacecraft's course would be altered in exactly the same way. More than one science fiction writer of the 1930s toyed with the idea, as in Lester del Rey's 1939 story "Habit," in which a rocket jockey wins a race by stealing a gravity boost from Jupiter. "I grazed around the side, was caught in [Jupiter's] gravity, and began to swing in an orbit," the narrator says. "That's what I'd been looking for, something to catch hold of out in space to swing me around without loss of momentum, and that's what I'd found; Jupiter's gravity pulled me around like a lead weight on a swung rope."

By the mid-1950s, with the Space Age fast approaching, a few scattered academics, including the members of the British Interplanetary Society, were discussing the concept in a serious, if rather general, way. In 1954 mathematician Derek Lawden wrote in the society's journal, "A number of writers have suggested that the fuel requirements of a journey between the Earth and the other planets might be reduced by taking advantage of the attractions of various bodies of the solar system." Lawden went on to admit, however, that "the method of calculating such perturbing effects and the economies to be expected do not appear to be widely known."

That was still pretty much the case in the summer of 1961. Although scientists at MIT, the Rand Corporation, and elsewhere had discovered cases in which a gravity maneuver could be beneficial (the Russians had already used the moon's gravity to shape the trajectory of their 1959 Luna 3 mission), no one at JPL was applying the principle in any systematic way to planetary mission design. In fact, says Minovitch, "Celestial mechanics was not looked at as a real serious problem. The real problem, and the underlying technical philosophy of space travel, was hardware development." Most space visionaries of the 1950s had been of the mindset that the way to reach farther into space was simply to launch ever more exotic rockets—which, of course, had yet to be developed.

When he arrived at JPL, Minovitch was assigned to a trajectory group headed by Victor Clarke, a laid-back engineer who'd been at the lab for five years. Clarke's group was work-

ing with a computer program to calculate one-way interplanetary trajectories and had plans for another program that would yield round-trip trajectories for Earth-Mars-Earth and Earth-Venus-Earth missions. The round-trip program required factoring in the effects of gravity at the target planet.

Minovitch contends to this day that Clarke assigned him to work only on the straightforward one-way trajectories, not the round trips. Clarke remembers it differently. Either way, Minovitch, who had no background in celestial mechanics, began playing around with vector analysis of spacecraft trajectories, which led him to a realization. Years later he wrote: "When I studied the relatively simple equations on my paper, these things just leaped out at me!"

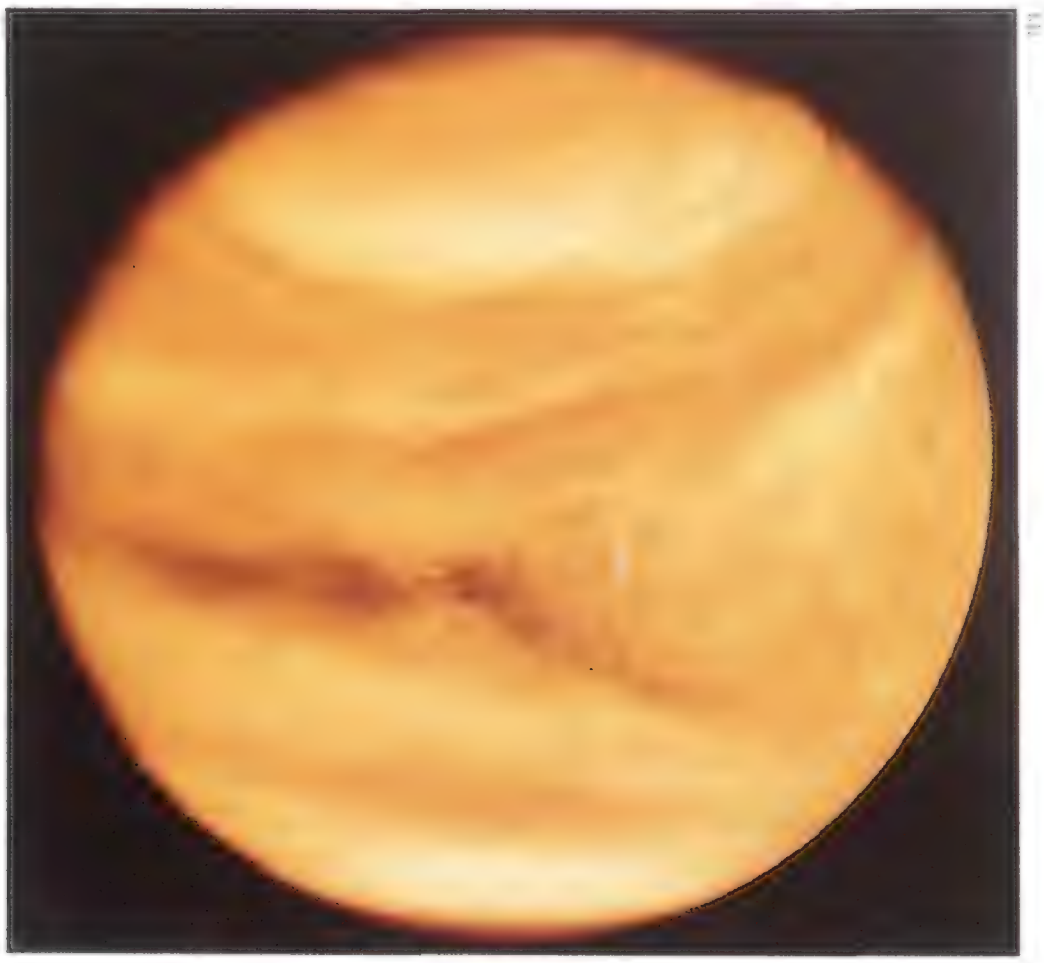
Most mission designers of the day, concerned as they were with producing nice, clean, elliptical trajectories, thought of gravity "perturbations" as annoyances to be canceled out with rocket burns. Minovitch's insight was exactly the opposite. Gravity swing-bys could be used to *replace* rocket burns. In fact, the most efficient way to reach any planet (except Venus, the planet closest to Earth) was to go somewhere else first, then use the intermediate planet's gravity for a free boost. It meant that any place in the solar system—the giant outer planets, even the sun itself—was accessible with relatively small launchers. You didn't need big nuclear rockets, as the textbooks said. All you had to do was get to Venus first, then let nature's own energy take over.

In August, before returning to UCLA, Minovitch wrote up his ideas in a JPL technical document. But he knew that his quick slide rule calculations weren't enough to prove the concept. He needed a powerful computer to perform the long and tedious calculations that could identify real trajectories.

Back at UCLA, Minovitch dove into the project independently, convinced that the technique he called "gravity propulsion" could change the course of space exploration. He took courses in FORTRAN programming and convinced his professors to give him access to what was then one of the most powerful computers of the day, an IBM 7090. He used a smaller JPL computer over Christmas break, and when he returned to work there the following summer he was allowed access to the lab's own IBM 7090s.

For the next two years Minovitch juggled a full load of graduate courses with his work on gravity propulsion. He was a man on fire. "For months, he wanted to talk about little else over dinner," recalls his college friend Lowell Wood, later a guiding spirit of the SDI missile defense concept. Minovitch would run his trajectories on the giant room-size computers late at night, when they weren't in demand. Less than an hour after Mariner 1—JPL's first attempt to reach Venus—exploded on the launch range, Minovitch parked himself in front of a 7090, taking advantage of the unexpected down-time. Working in the pre-dawn hours, often by himself, he tried different combinations of launch dates and target planets. He had punched in the entire planetary ephemeris (a table showing the precise positions of the planets over time) himself. It took two weeks. He didn't care. Each time he heard the buzzing of the computer tape as it filled with data, he knew he had another "hit," another viable gravity-assist trajectory. The work was Herculean, mind-boggling. "He had this fixation on understanding everything that could possibly be done, every launch date, every planetary combination, everything," says Wood.

The folks at JPL didn't quite know what to make of this brilliant, obsessive grad student who only came out at night, loading computer paper into his beat-up car to haul back to UCLA for more number crunching. They got a big laugh the time he forgot his badge during one



Minovitch determined that it would be quicker to send probes to other planets by having them swing by Venus first. Mariner 10 also used its Venusian flyby for science, returning ultraviolet images of Venus' upper cloud layers that revealed how quickly the atmosphere circulates around the planet.

CHAD SLATTERY (2)

Fran Sturms (right) and Joe Cutting (opposite) grasped the importance of the gravity assist concept. While investigating possible trajectories at JPL, they dubbed their group the "Cheap Missions Office."

of his midnight runs, tried to climb the fence, and got caught by the guard.

Not surprisingly, he didn't fit in well with the more practical-minded engineers and scientists at the lab. Although many of them could also be hard-charging, even a bit eccentric, they were more collegial, dropping into one another's offices to shoot the breeze, working out problems on blackboards together. Minovitch kept to himself. Norm Haynes, who later managed the Voyager project during the Neptune flyby, joined the trajectory group in 1962, and, though his office was next door to Minovitch's, Haynes never saw him. "I didn't even know who he was," Haynes says. "We just knew he was there because he'd leave these giant stacks of computer printouts, and the stacks just kept getting bigger and bigger."

At the same time, Minovitch was becoming increasingly frustrated with the atmosphere at JPL. "When I came to the lab," he recalls, "my feeling was it was going to be an academic institute, or like a subset of Caltech, where elite theoreticians were working. And that was not the case." He was more at home with academics and thought of engineering as, well, the equivalent of manual labor. This was the nation's premier space laboratory? They didn't even seem to realize the importance of his idea! Remembers Wood, "[Minovitch] was constantly complaining that he couldn't get the people at JPL interested."

There were, of course, plenty of people at the lab who understood Minovitch's concept. They just weren't as excited about it as he was—or didn't act like it, anyway. Minovitch was especially frustrated by the reaction of his own boss. Perpetually up to his eyebrows in memos, meetings, and project-related deadlines, Vic Clarke didn't have much time to discuss his summer employee's research. At first, some recall, he had even been among those who argued that the physics of the idea were all wrong and that there was no such thing as a free ride. According to Minovitch, Clarke "truly believed that the underlying theoretical concept violated the laws of conservation of energy." Yet the energy wasn't created from nothing. It was stolen from the planet's own enormous orbital energy.

To understand how a gravity assist works, think of a rapidly spinning carousel with a rider standing on its edge. A passerby running up to the carousel could briefly grab hold of the rider's hand and get a boost from the carousel until he releases his grasp and is sent running off more rapidly in a different direction. The carousel, for its part, would have slowed slightly. (JPL engineers later calculated that when Voyager picked up some 35,700 miles per hour of velocity from Jupiter's gravity, the planet's orbit slowed down by one foot per trillion years.) Gravity assists can also be used to slow a spacecraft. In the case of Mariner 10, the spacecraft was slowed by Venus as it turned inward toward Mercury. During the maneuver, Venus speeded up ever so slightly in its orbit.

Gary Flandro, then a Caltech graduate student and later the discoverer of the Voyager planetary "grand tour" opportunity, remembers the arguments. At first, "Clarke did not understand that you could get an energy gain when you did a planetary flyby," says Flandro. "He and Mike had many, many verbal battles over that one." (Today Clarke dismisses the assertion that he didn't understand the concept as "hogwash.") Clarke eventually did allow Minovitch to use JPL's computers to explore the concept more fully but he never placed it very high on his priority list. JPL had its hands full with simple trips to Venus and Mars. Multi-planet missions and the outer solar system were still off in the future. Why worry about them now?

Minovitch kept beavering away nonetheless, running every conceivable combination of planetary encounters on the UCLA and JPL computers. He had Mars missions. He had Mercury missions. He even had missions to Neptune and Pluto. But he was working in virtual isolation. "He was very closed in what he wanted to reveal about his work," remembers Roger Bourke. "He considered it such a secret." Which, along with the lack of any project-related urgency, helps to explain why, three years after Minovitch published his first paper on gravity assist in 1961, the concept was still outside the mainstream of thinking at JPL.

In 1964 Clarke left the trajectory group, and Elliot "Joe" Cutting, one of the analysts in the section, took over. It wasn't long before Cutting turned his attention to gravity assist. "I was quite

interested in what Mike had done," Cutting says. "I'd read his stuff, and I said 'Gee, this looks kind of interesting. Is it practical?' " Cutting assigned Fran Sturms, who had recently arrived at JPL, to help him find out. They picked a test case—a 1970 trip to Mercury, using a gravity maneuver around Venus—for a detailed feasibility study. One major concern—some naysayers even thought it would be a showstopper—was navigation, a problem Minovitch had never addressed in any detail. If a spacecraft missed its target point at the first planet even slightly, it could be hurled off in the wrong direction. (When Mariner 10 used the technique, each mile of error at Venus would have translated to a thousand-mile miss at Mercury.) The key was being able to hit your aim point exactly. Cutting and Sturms not only showed that the navigation requirements were well within the state of the art, they produced a whole mission profile, complete with launch dates and energies, flight times, and aim points. True to Minovitch's premise, they found that the gravity assist at Venus reduced fuel requirements—by a whopping 70 percent. Instead of needing a big, expensive rocket to reach Mercury, as conventional wisdom argued, you could get there with a modest Atlas-Centaur and some help from Venus.

Cutting's group started calling itself the Cheap Missions Office. Bourke, who later headed JPL's advanced studies group, sees Cutting and Sturms' work as a watershed in the development of gravity assist. Before their report, he says, "the whole multi-planet trajectory business was thought of as kind of a curiosity but not a practicality." With an actual mission profile on the shelf, people began to think, *My God, maybe we could actually do this.*

Minovitch was still working summers at JPL, but not on the Venus-Mercury mission study. Although Cutting had included his name on a list of team members, Minovitch was more interested in extending his already massive compendium of gravity assist possibilities. He came up with gravity-boosted manned missions to Mars and outer solar system missions, including the Voyager opportunity later found independently by Flandro. The list just kept getting longer.

Ironically, after all those hundreds of hours Minovitch spent learning FORTRAN and punching in planetary position data and hauling printout paper around in the back of his car, his custom-built program got little use at JPL. The lab's programmers tried but found it too idiosyncratic. The programs they developed were faster and more efficient and produced perfectly useful trajectories.

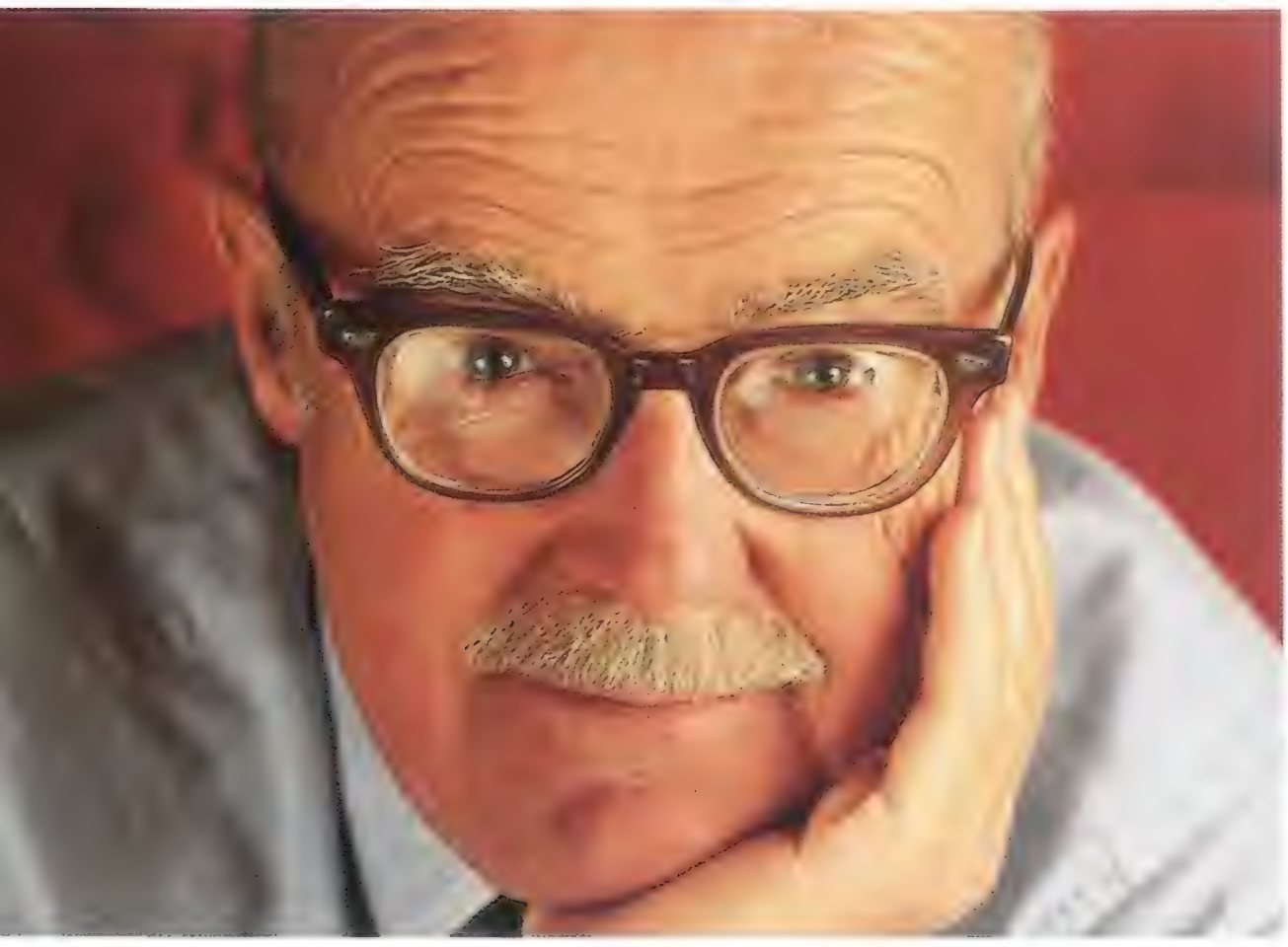
When Cutting and Sturms published their findings in 1964, the idea of gravity assist was still a novelty. (At a professional society meeting the following year, they had to attach a disclaimer saying that neither JPL nor NASA had endorsed the mission.) But by decade's end the concept was established enough to be included in a real project. In 1969, NASA approved a Venus-Mercury mission with a cut-rate price of $98 million. The launch was set for November 1973. By the time Mariner 10 radioed back its last burst of data in March 1975, it had visited Venus once and Mercury three times, giving NASA more bang for the buck than any planetary project up to that time. By then practically every mission on NASA's drawing board—the Pioneers, the Voyagers, and later the Galileo exploration of Jupiter and its moons—relied heavily on gravity assist to reach its destination.

After Minovitch earned his Ph.D. from the University of California at Berkeley in 1970, he returned periodically to JPL to work on various assignments. In 1972 he was awarded the NASA Exceptional Service Award for his contribution to the development of the gravity assist concept.

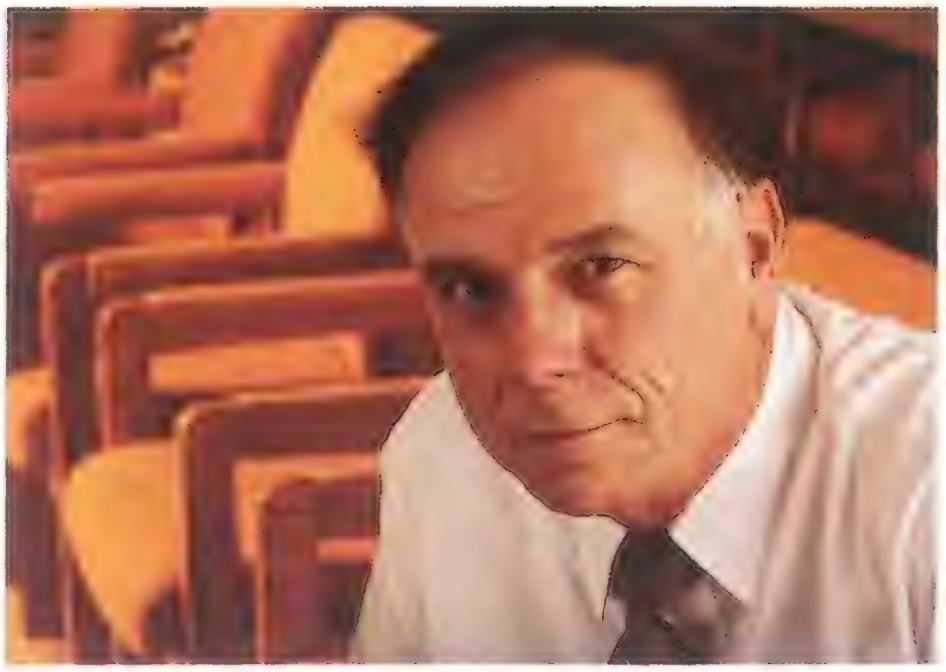
And that's around when the trouble started.

Minovitch felt slighted at having been passed over for a more prestigious citation (he was later angered when Clarke applied for a joint monetary award). What's more, he became increasingly concerned about what he saw as a deliberate attempt to downplay his role in discovering gravity-assist propulsion.

In 1974, the year Mariner 10 reached Mercury, he threatened to sue JPL over statements made by Clarke and others to University of Kansas historian Norriss Hetherington, who planned to publish a paper in a professional journal on the origins of gravity assist. Minovitch challenged statements in the paper suggesting that it was a natural result of ongoing work at JPL, not a unique idea. The episode touched off an internal inquiry at JPL, caused a blizzard of memos and letters between Hetherington and Minovitch, between Clarke and his bosses at JPL, between everyone and



everybody. Hetherington and the journal backed off, not wanting to get involved in a lawsuit.



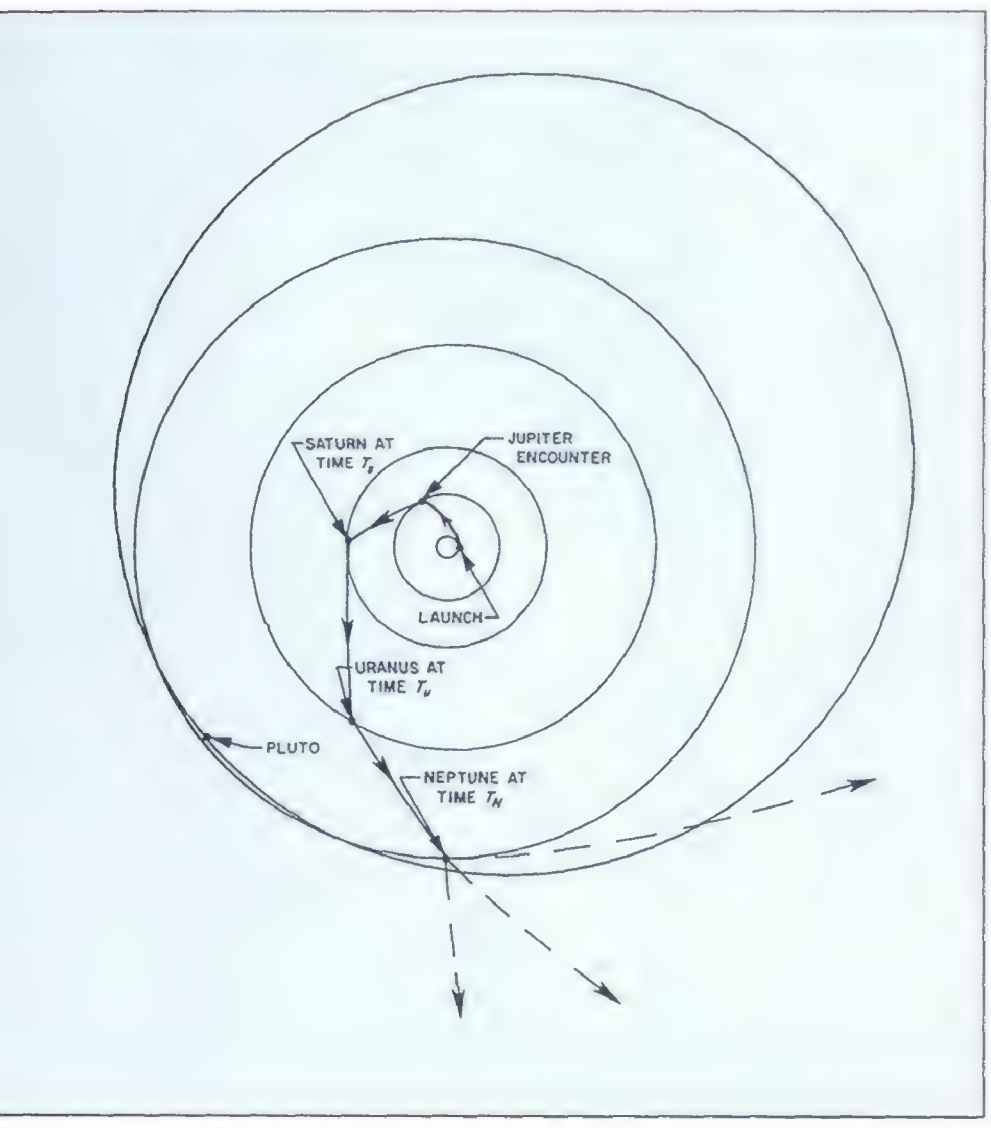
RICH MAYS

One trajectory Minovitch discovered was a gravity-assisted tour of the outermost planets. Later known as the Grand Tour (below), the trajectory was discovered independently by JPL's Gary Flandro (left) and used by the Voyager spacecraft.

So who *did* invent gravity assist? John Niehoff of Science Applications International Corporation, who started working on trajectory design in the early 1960s, states flatly, "Mike was the first person in the Space Age to recognize and demonstrate the utility of planetary gravity fields in spaceflight." But, he adds quickly, "The problem I have with Mike is that he has consistently been unwilling to acknowledge the contributions of anyone but himself."

Certainly there were others before Minovitch who had been aware of the concept, who had even started thinking about its application to spaceflight. Ask the people who were working in the field of astrodynamics in 1961, and they'll tell you it was just a matter of time before someone looked into the problem as deeply as Minovitch did, that gravity assist was an evolutionary development, not a single person's invention. Fran Sturms, who thinks Minovitch's contribution was critical, says nonetheless, "He seemed to think that his early idea was so fundamental that it was something world-class. I have a little trouble with that. It's the kind of thing that happens around here all the time. There are a lot of smart people who work here, and people are always coming up with new concepts and ways to do things."

Minovitch's cantankerousness probably makes it harder for others to give him the sole credit he wants. William Kosmann, a former JPL mission planner who collaborated with Minovitch on two papers delivered to the International Astronautical Federation in 1990 and 1991 that told his version of the story in exhaustive detail, admits that Minovitch's personality can put people off. When Kosmann, a much younger man, was working on the Voyager mission in the late 1980s, he decided to find out who had invented the ingenious technique that made it all possible. Kosmann determined to his own satisfaction that Minovitch should get most of the credit, and wrote a chapter in the JPL-produced *Voyager Neptune Travel Guide* saying as much. He also arranged to get Minovitch invited to JPL for the 1989 Neptune encounter, the first time anyone had thought to ask him to one of the flybys. After a meeting with Voyager project officials and a photo session, Minovitch says, "I had tears in my eyes for two months."



Minovitch, who left JPL for the last time in 1972, started a business in Los Angeles called Phaser Telepropulsion, Inc., published a couple of papers on laser-powered rocket propulsion, and eventually got into a minor dispute over who should get credit for *that* concept—Minovitch or Arthur Kantrowitz of Avco Corporation. But the last few years have been kinder. There was the Neptune invitation and the two IAF papers, and then, in 1992, a segment on the PBS television series "Space Age," including footage of his boyhood, that extolled Minovitch as the man who opened up the solar system. Now he says he wants to leave all the rancor behind him.

But it doesn't take much to get him riled up again, to get him talking vaguely of lawsuits and investigations by the National Academy of Sciences if people don't tell the story the way he'd like it told. He wants peace, but on his own terms.

As for the other participants, most of them say they don't care who gets the credit. Clarke, who has left JPL, says he can hardly stand to talk about it anymore. The controversy of 20 years ago left every participant with a sour taste that still lingers.

Some aren't even aware that it's been a matter of controversy. Derek Lawden is the British mathematician who wrote about the practical benefits of planetary gravity back in 1954; asked what he thinks about Minovitch's place in history, Lawden has to rack his brain. "Who?" he asks.

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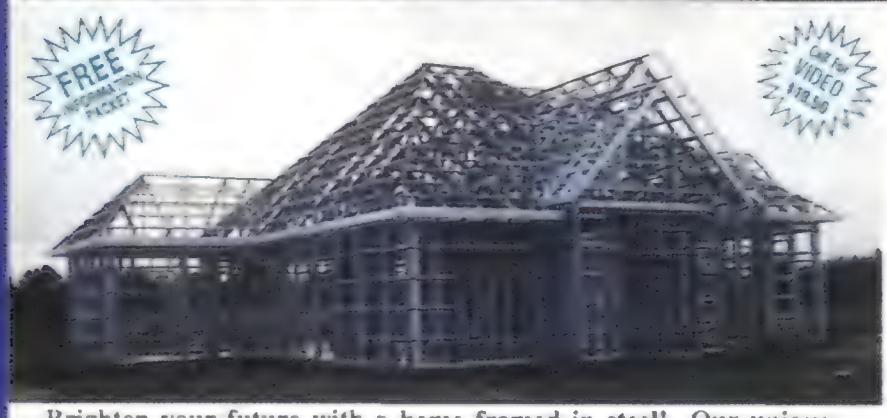

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The November Oscar Incident

Airline pilots are haunted by a missed approach that left only one casualty—the captain.

by Stephan Wilkinson

On November 21, 1989, a British Airways 747 on an instrument approach came within a stone's throw of crashing at London's Heathrow Airport. Flying in thick fog, the huge airplane was far enough to the right of the approach course that when the captain discontinued the approach, he was actually outside the airport fence, paralleling a highway crowded with morning commuter traffic. Before the airplane began gaining altitude, it came within 75 feet of the ground. As the 747 thundered past the nearby Penta Hotel, which is 70 feet high at its tallest point, car alarms all over the parking lot began to chirp and wail, their sensors tripped by the airplane's passage.

The pilot in command of G-AWNO (the airplane is usually referred to by the last two characters in its registration: "November Oscar") was William Glen Stewart, a 53-year-old British Airways captain with 15,000 flight hours. On his second attempt he landed the airplane routinely, but even before he had parked at the gate, phones at British Airways' headquarters were ringing. It would be Stewart's last landing, for he lost his job, and more. That much is known.

Beyond that bare summary, however, lie two diverging accounts of not only what caused the incident but where the blame for the botched approach lay and how that blame should be apportioned. It is a landmark case in aviation history, for William Glen Stewart was not simply censured or cashiered—the usual consequences even in fatal accidents. Instead, he was judged to be a criminal.

In the past, criminal proceedings have been brought against pilots who flew drunk, showed off by flying under bridges, or committed other acts of intentional stupidity. Two Korean pilots were jailed in Libya in 1990 after landing short in Tripoli, killing 72 passengers and at least five others. In 1983, a Swissair crew was convicted and fined in Greece after skidding off the end of a wet runway at Athens; 14 passengers died. Yet Stewart had landed safely; no one had been killed, injured, or—aboard November Oscar at least—was even aware they were characters in a fateful drama.

CHAD SLATTERY

Stewart's defenders portrayed him in court as doing his best to get the airline's passengers to their destination as economically as possible—playing the cards he was dealt. His accusers held that Stewart blew an instrument approach that he never should have attempted, risking the lives of his 255 passengers, as well as numerous motorists and perhaps even hotel occupants.


THE TIMES WEDNESDAY APRIL 24 1991

BA jumbo jet pilot missed buildings by 12ft, court told

By HARVEY ELLIOTT
AIR CORRESPONDENT

ONE of the worst accidents in aviation history was avoided by 12ft when a British Airways jumbo jet carrying 255 passengers skimmed buildings 200 yards from the main runway at Heathrow after missing its landing approach, a court was told yesterday.

placing his aircraft, passengers and people on the ground in this perilous position." Although he was an experienced pilot, aged 54 and with 14,750 flying hours, "sometimes experienced pilots, like experienced motorists, fall below the standards required. It's just that"

On May 8, 1991, a jury at Her Majesty's Crown Court in Isleworth, England, hesitantly agreed. In a split verdict (10 to 2) they found William Glen Stewart guilty of negligently endangering his aircraft and passengers. It was the first time in the history of British aviation that an airline pilot was found to be a criminal—was, in fact, even charged with being a criminal—as a result of the pursuit of his duties to what he believed to be the best of his abilities.

When I first heard of Glen Stewart and his sad fate, it seemed another bitter example of the indignities that airline pilots occasionally suffer at the hands of journalists, lawyers, and others who understand nothing of the flying profession. Stewart had already been convicted in the press, in breathless accounts of how he'd mistaken the nearby highway for the runway and had actually been trying "to crashland" on it, of how he'd come so close to the hotel that he'd set off fire sprinklers. The press particularly liked the sprinklers.

I've never flown for an airline, but my sympathies were aligned with those of a friend, a former flight instructor of mine and now a 767 captain, to whom I described the affair. "What was the guy found guilty of?" he asked in amazement.

"Endangering his passengers," I said.

"I do that every day I fly," he said with a laugh. "That's aviation."

As I delved deeper into the November Oscar incident, I would learn that things weren't so simple. How did this happen? Why did it happen? Though British Airways and the British Civil Aviation Authority (the equivalent of the Federal Aviation Administration) have either refused or ignored repeated requests for interviews, both British and American wide-body pilots familiar with the November Oscar incident as well as safety experts and others contributed their insights during my research. Many pilots fear that their careers could be ruined if they were to speak candidly on a subject that obviously cuts to the core of some of the airline industry's darkest secrets. For that reason their names don't appear here.

Stewart's problems began at a Chinese restaurant in Mauritius, in the Indian Ocean off Africa. There, he and his entire flight and cabin crew, plus flight engineer Brian Laversha's wife Carol, dined during a layover before flying on to Bahrain and then to London. Bahrain-Heathrow would be the last leg of a trip that had begun in Brisbane, Australia.

By the time the crew reached Bahrain several days later, many were doubled over by gastroenteritis. Stewart was unaffected, but his copilot, 29-year-old Timothy Luffingham, and flight engineer Laversha were poleaxed by the bug. Carol Laversha suffered worst of all, and a Mauritian doctor prescribed both a palliative and a painkiller for her, telling Brian that he too should take them if his own symptoms worsened.

The doctor was not a British Airways-approved flight surgeon, but the approved doctor, who was too far away to minister to the crew, suggested the substitute physician, having been told that the new man would soon be added to the airline's list. The examining doctor seemed unconcerned that the pilots were scheduled to fly in two days. British Airways would later accuse the crew of not following approved medical procedures.

"I could get pretty angry at a lot of the characters in this affair," says a former airline pilot who today flies cargo widebodies for the Air National Guard. "Nobody ever consciously sits down and says, 'Let's make it impossible for the crew to get to the right doctor, so that we later can claim company deniability when they go to the wrong one,' but that's what in effect happens.

"This was apparently a doctor who didn't even understand the effects of self-medication in a pressurized aircraft on the performance of a complex task, and right there is a microcosm of everything that pressured the crew to get the job done. That doctor's vested interest is in sending flight crews out to fly. Certainly if he ever expects to work for BA again he isn't going to ground crews right and left. The company *wants* you to fly."

For Stewart, it turned out to be a difficult flight. Unanticipated headwinds cut into November Oscar's fuel reserve. Copilot Luffingham was floored again by his stomach bug and had to leave the cockpit for several hours after taking some of Carol Laversha's painkillers. The crew considered landing at Tehran but deemed it politically too chancy.

Stewart flew for over five hours, much of it in the dark,

British Airways captain Glen Stewart had years of experience flying in the poor weather conditions typical of Europe.


INS PICTURES

Approach to Minimums

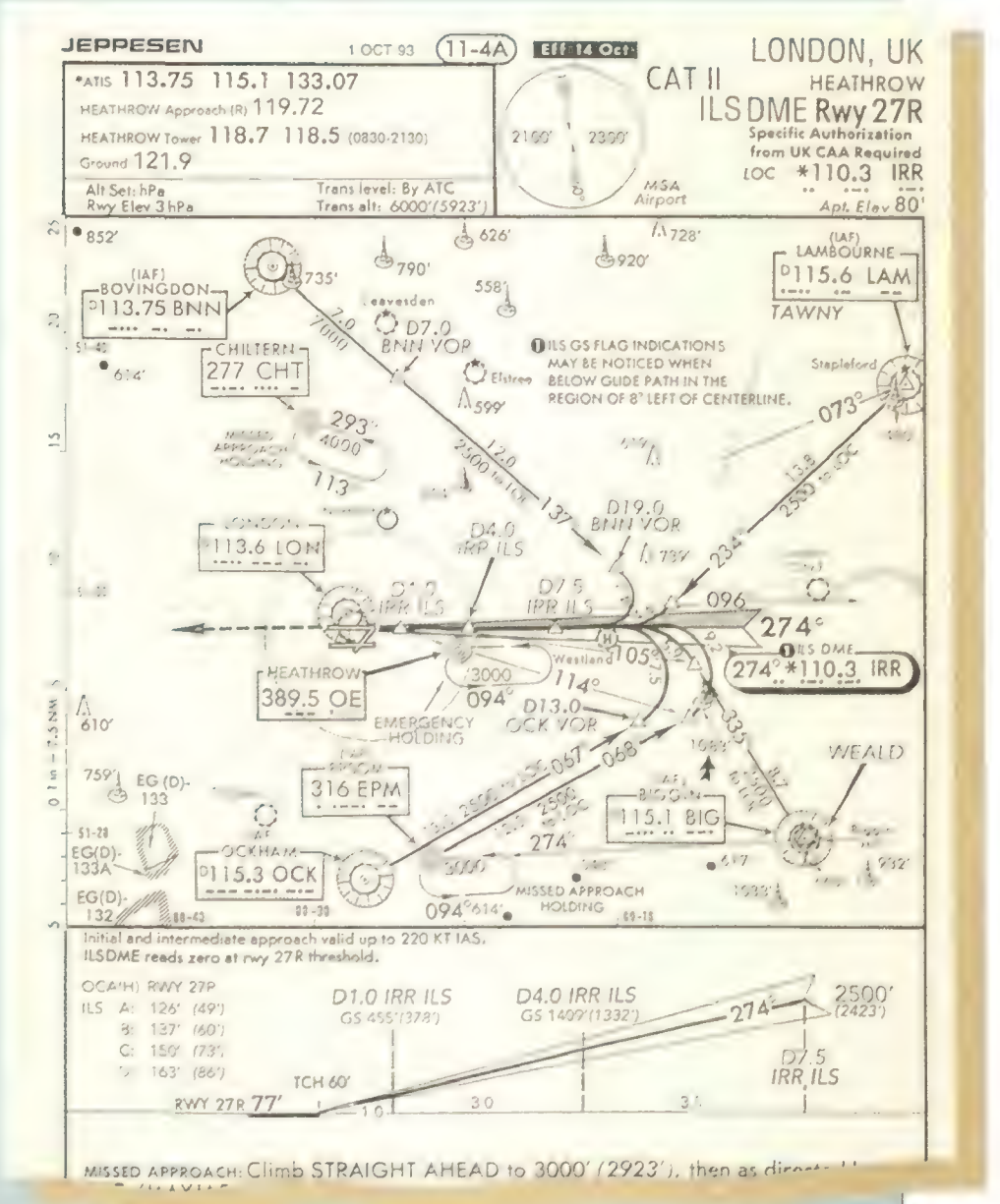
The most precise instrument approach procedures available at most airports rely on a navigation aid called the **Instrument Landing System**, or ILS. An ILS provides two radio beams aligned with the runway: a left-right **localizer** and an up-down **glide slope.** The localizer is a horizontal beam aligned with the runway centerline that indicates to the pilot whether the airplane is left or right of the approach course. The glide slope provides a fan-shape vertical beam aligned along the ideal descent slope to the runway's touchdown zone and indicates to the pilot whether the airplane is above or below that path. Both components are represented in a single cockpit display, the most basic of which presents two pointers, one moving left-right, the other up-down, to indicate the airplane's deviation from the center of the approach. When the airplane is on course, the pointers are crossed and centered. The flight director display aboard G-AWNO is more sophisticated, but it too presents the pilot with this basic course information.

The dimensions, navigation fixes, and approach paths for all ILS approaches in the world are published by government agencies and private companies in the form of small diagrams called approach plates, such as the one shown here for the approach Stewart was flying. Depending on how the airplane is equipped and whether the crew is qualified, increasingly stringent criteria can apply to the same instrument approach. Those criteria can determine the **decision height**—how low a pilot can descend in cloud to identify the landing runway visually before having to decide to abort the approach and try again or land somewhere else. The criteria also set limits as to how adverse the visual conditions along the runway can be—how far ahead the pilot can see. An approach to **minimums** means that airport weather exactly matches the limits for that approach and a pilot can expect to see the landing runway at the very moment he must decide whether to continue to descend or go around.

An airplane and crew approved for Category II approaches to Heathrow runway 27 Right can descend to 100 feet above the ground in visibility of as little as 350 meters (roughly 1,150 feet) before going around. In general, Category I doubles the decision height, while Category III cuts it in half. A 747 landing in Category III conditions is literally landing blind. When the landing gear is 50 feet above the ground, the airplane should begin flaring to land, yet the cockpit—considerably higher than the wheels—is still in the clouds.

Because the task of landing in conditions requiring Category II and III approval is so demanding, the 747 Stewart flew was essentially controlled by the autopilot system while the crew monitored the instrument panel. Autopilots **capture** the radio beams transmitted by the ILS and fly the airplane along those beams to touchdown; even the landing flare can be performed automatically. But November Oscar's two autopilots may not have been able to capture the localizer. When the airplane turned in to start its approach, the autopilots were disconnected for a time, and the airplane was flown manually. Later, an attempt was made to re-engage the autopilots, though it seems clear from the ground track that the airplane never settled on a stable approach.

Regardless of any suspected fault in the autopilot system (none was ever identified), a professional pilot with Stewart's experience is expected to handle such occasional adversities, and in all cases, the crew is responsible for monitoring the instruments to ensure that the airplane is flying the ILS properly.



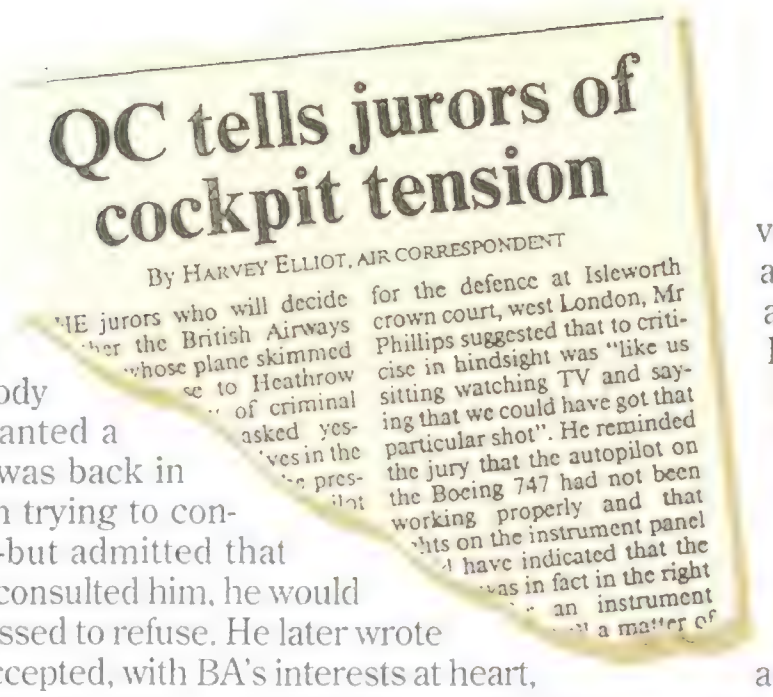
with only a 15-minute respite. The crew also became dehydrated, and Laversha would later testify to the airline's incident review board that because he had chastised a flight attendant for entering the cockpit without permission, she had retaliated by ignoring them.

Over Frankfurt, the crew got word that the weather at Heathrow was down to the ground: it would probably have to be a Category III landing (see "Approach to Minimums," above). Tim Luffingham did not meet the requirements to participate in a Cat III or even a Cat II instrument approach, but Stewart and Laversha did. Stewart was in fact a highly experienced instrument pilot: he had flown approximately half his airline hours as a British European Airways short-haul pilot, in what is generally agreed to be the worst winter flying weather an airline pilot can encounter. But like most airline pilots, he had never made a Cat III approach to minimums in his entire airline career, and Luffingham, new with BA, hadn't even had the mandatory simulator training.

With 255 dozing passengers dreaming they'd soon be breakfasting in London, there had to be a way around such an embarrassing hitch. There was. Stewart radioed British Airways' Frankfurt office and asked them to telephone Heathrow and obtain permission for Luffingham to help out on this one approach in order to get November Oscar home. British Airways routinely gave such dispensations, and they did it again this time. Stewart never volunteered the information that the very pilot for whom he was requesting a dispensation might at the moment be in the blueroom, con-

vulsed by gastroenteritis, and nobody on the ground asked.

Luffingham would also testify that nobody asked him if he wanted a dispensation—he was back in the first class cabin trying to control his diarrhea—but admitted that even if Stewart had consulted him, he would have been hard-pressed to refuse. He later wrote in a deposition, "I accepted, with BA's interests at heart, the dispensation to operate to category III autoland conditions. I personally would not mind if we had diverted. [But] what would BA have said to the captain if he had diverted without asking for a dispensation? What would they have said to me if I had not accepted it?"



QC tells jurors of cockpit tension

By HARVEY ELLIOT, AIR CORRESPONDENT

"HE jurors who will decide ...ther the British Airways ...whose plane skimmed ...se to Heathrow ... of criminal ...asked yes- ...ves in the ...e pres- ...ilot for the defence at Isleworth crown court, west London, Mr Phillips suggested that to criticise in hindsight was "like us sitting watching TV and saying that we could have got that particular shot". He reminded the jury that the autopilot on the Boeing 747 had not been working properly and that ...hts on the instrument panel ...d have indicated that the ...as in fact in the right ... an instrument ... a matter of

This is the heart of the professional pilot's eternal conflict. Into one ear the airlines lecture, "Never break regulations. Never take a chance. Never ignore written procedures. Never compromise safety." Yet into the other they whisper, "Don't cost us time. Don't waste our money. Get your passengers to their destination—don't find reasons why you can't."

Approaching London, November Oscar was given a routine hold northeast of Heathrow. Luffingham, by this time back in the right seat, was annoyed that Stewart insisted on hand-flying the racetrack-shape holding pattern. Luffingham felt the autopilot could have done a smoother job, but Stewart preferred to fly it himself. It's possible the autopilot did not have his full confidence—an opinion others shared.

November Oscar was a 747-136, an early series designed in the 1960s; British Airways refers to these older 747s as "the Classic Fleet." And the Sperry SPZ-1 autopilot on the 747 was based on an earlier design. It was, as British air safety expert David Beaty put it to me, "never designed for that aircraft. It was bolted on and had to be nursed carefully."

Laversha, for his part, didn't like the looks of the fuel levels. "While we were in the hold, I told him, 'Come on Glen, we've got two minutes of [holding] fuel left, let's buzz off to Manchester,' " he recalls. "But he was a very determined man." Stewart had the weather reports for both Manchester and London Gatwick, and the crew discussed the options. They knew the weather was better at Manchester, and Stewart was on the verge of heading there when Heathrow called and cleared November Oscar for an approach. The Heathrow weather had improved slightly, but there was one further complication: they were to land on runway 27 Right rather than 09 Left. The wind had changed.

"That was a very strange morning," another captain said later. He had landed on the opposite runway before the switch. "We ran through a thick bank of fog on short final and in fact landed below limits," he told me. "The runway actually disappeared in the flare."

That captain's admission that he broke the ceiling-and-visibility limits on an instrument approach illustrates that airline pilots frequently encounter weather conditions and visibility that instantly render their landings illegal. Do you "hold what you've got" and land when you're already committed but run into rogue fog, or do you attempt a blind go-around from a few dozen feet above the runway? Most professional pilots would opt for the former.

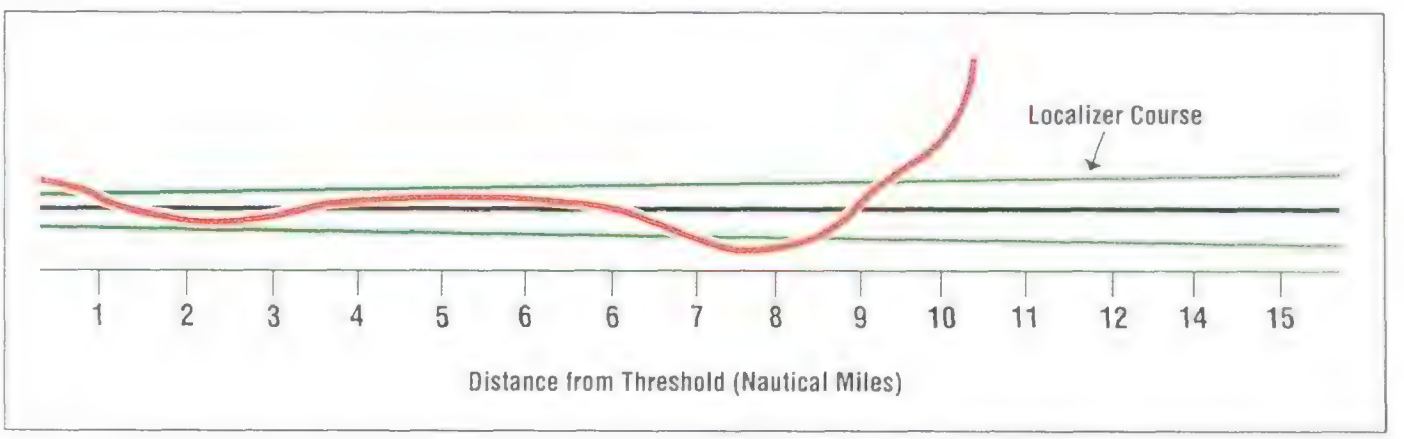
Stewart's approach was a hurried affair, complicated by a number of factors. Any one or two might have been inconsequential, but taken as a group of sudden additions to a shorthanded, ailing crew's workload, they turned a routine approach into a flying can of worms.

The last-minute runway switch required a reshuffling of charts, procedures, and mental pictures. A 10-knot tailwind at altitude meant November Oscar would be steaming down the approach at a faster clip. The approach controller turned Stewart onto the localizer 10 miles from the runway rather than the customary 12 or more, making the approach even more hurried. He also did it at an altitude that required the two autopilots to intercept the glide slope and the localizer almost simultaneously, which may account for why they didn't fly the approach properly.

Then, when the 747 was halfway down the localizer, the control tower radioed that some approach lights apparently had failed, prompting Laversha to take a hasty look through a checklist to see how that affected their planned procedures. The tower controller also withheld clearance for November Oscar to land until the very last moment—actually slightly later than regulations permit—because an arriving Air France jet was still on the runway, groping for its turnoff.

What truly tightened the noose, however, was that in order to make a legal Category II or III approach, November Oscar's autopilots had to function perfectly. On this day, however, they were trundling back and forth through the localizer beam like a clumsy bloodhound not quite able to catch the scent. And Laversha was worried about Stewart: tired, irritable after all that time in the saddle, trying to monitor autopilot status lights and navigation instruments largely solo. Copilot Luffingham was little more than an observer. "I was not qualified to make this approach and could not make any suggestions as to what was wrong," he would lat-

A ground track of November Oscar's path shows how the autopilot wandered left and right of the correct course.



INS PICTURES

During the trial, Stewart was dogged by the media. Some felt the press coverage helped predetermine his conviction.

er testify to BA's safety investigators. Luffingham had decided his best course was to stay out of the way.

Stewart was now "illegal" and had been ever since the airplane had descended below 1,000 feet above the ground. Though there are tricky rationalizations that can be argued endlessly, both airline procedures and CAA regulations seem to specify that a Category II or III approach must be discontinued at that point unless all of the required equipment, most notably the autopilots, is functioning perfectly and tracking the Instrument Landing System.

Many highly competent professional pilots have said of November Oscar, "I'd have thrown away the approach, gone to my alternate or tried again. No question about it." But other professionals, some of them with BA, believe what one pilot expressed: "Look, he was concerned about fuel. He had a first officer who was no help. He knew a diversion to Manchester would cost the airline a minimum of $30,000. He realized he'd be sitting in the chief pilot's office trying to explain how he got himself into a position that required a missed approach in the first place. He figured the autopilots would settle down. And I'll bet he was convinced he'd break out at Cat I limits and could take over and hand-fly it the rest of the way. I can understand why he carried on."

It might have worked. If it had, nobody would ever have heard of November Oscar, and Glen Stewart would still be a British Airways captain. With the radar altimeter indicating only 125 feet above the ground, the runway still wasn't in sight, and Stewart made the mistake that turned a routine go-around into newspaper headlines. Always conscious of his passengers' welfare and comfort—he took the trouble to learn how to make cabin announcements in Japanese—Stewart had already told the crew that if a go-around was needed, it would be done gently rather than with the kind of full-power flurry that has everybody whiteknuckling their armrests.

And it *was* a leisurely go. Too leisurely. November Oscar sank another 50 feet. Stewart and Laversha also caught a glimpse of the approach lights out the left window, and it's not hard to imagine that Stewart briefly considered sliding over to the left and saving the approach. Said one U.S. jumbo jet instructor pilot familiar with the November Oscar incident, "This is a pilot who was critically low on fuel, which probably was one reason why he waited a second before going around. At decision height on a Category II approach, you look to see the slightest glow of approach lights, you wait 'one-potato,' see if anything comes into sight.

"At some point, you also become complacent on a familiar approach, you're so used to it. [Perhaps] a thousand times before, he'd watched that same autopilot do strange things on the same approach to the same airport, and he'd break out at 200 or 500 feet and make a play for the runway. And on the crew bus everybody says, 'Boy, that autopilot sucked again today.' "

Stewart's second approach, though the landing would elicit applause in the cabin, was not a happy affair. Luffingham noticed that his captain's hands were shaking as November Oscar climbed out and then was radar-vectored back for another try. Stewart was also "cursing under his breath," said Laversha. The copilot even gently suggested that *he* fly the second approach, but Stewart waved him away. Stewart then announced that this would be "a no-limits attempt at 27R"—shorthand for *tires on concrete this time no matter how low we have to go*. It is a procedure not authorized in any manual or rulebook, but it is one that many a rational pilot will employ when fuel is critically low.

On the way back to the crew room after shutdown, Stewart's mind was probably racing, wondering about the consequences of his missed approach. When he found a note in his company letterbox requesting that the crew see the chief pilot, he told Brian Laversha to collect his wife and go home, that Stewart would say they'd already left.

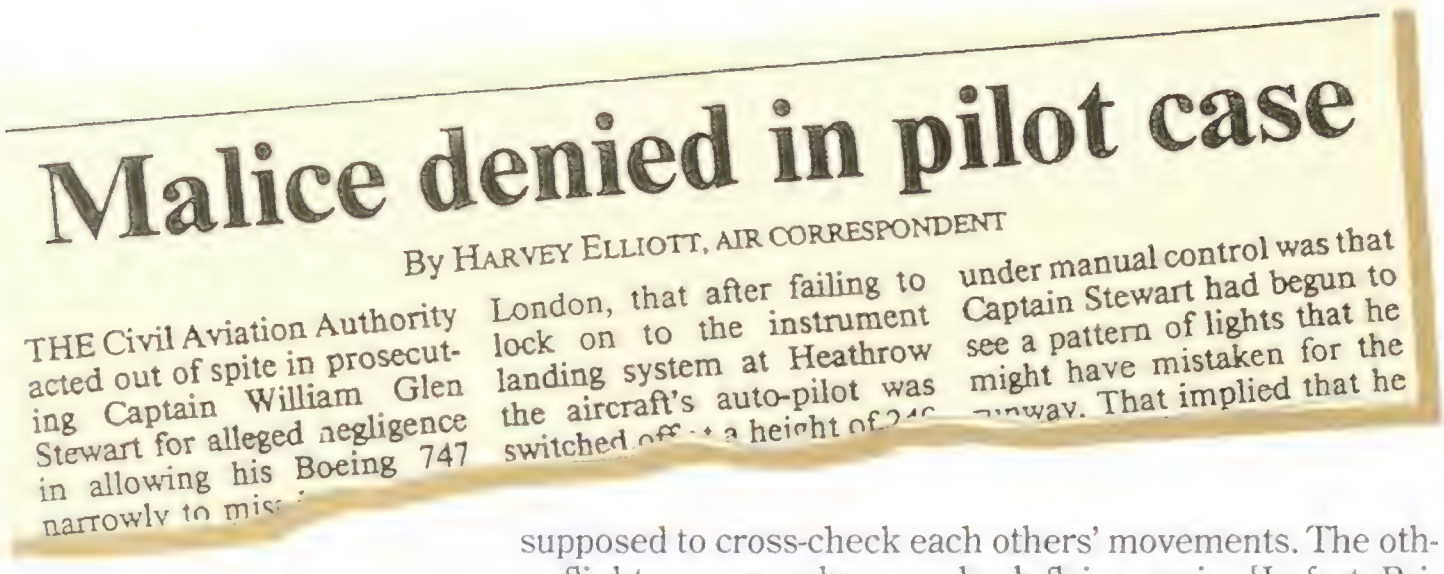
Stewart also balked, refused to speak with a BA air safety investigator, and drove the 25 miles straight home. His wife Samantha remembers: "It was the same sort of morning as after any long trip. He was tired but we talked about Mauritius, because we'd both been there together on vacation. An hour later, he said, 'I'm off to bed, but you might get a call from BA, because there was a go-around.' It wasn't anything I thought important."

It was. "He got a call around eight that evening saying the crew had been suspended," Samantha Stewart says.

Three days later, Glen Stewart wrote letters to both Brian Laversha and Tim Luffingham unstintingly praising their airmanship under difficult conditions and accepting full responsibility "as both Captain and the handling pilot" for the incident. British Airways investigated the affair, and finally issued a report castigating Stewart and chiding Luffingham and Laversha as well. Stewart was demoted to first officer, relegated to flying out the rest of his career in the right seat. And the CAA reduced his license to copilot status.

That was too much for a proud, stubborn Scotsman who had begun commanding Royal Air Force aircraft at the age of 21, who had devoted much of his adult life to British Air-

ways, and who was being disciplined for—as he saw it—doing the best he could. On April 2, 1990, Glen Stewart resigned from BA. He spent the next three days learning how to use a word processor, then set out to appeal the CAA's license downgrading.



Malice denied in pilot case

By HARVEY ELLIOTT, AIR CORRESPONDENT

THE Civil Aviation Authority acted out of spite in prosecuting Captain William Glen Stewart for alleged negligence in allowing his Boeing 747 narrowly to mis[illegible] London, that after failing to lock on to the instrument landing system at Heathrow the aircraft's auto-pilot was switched off [illegible] a height of 24[illegible] under manual control was that Captain Stewart had begun to see a pattern of lights that he might have mistaken for the [illegible]runway. That implied that he

Others saw it differently, of course. Stewart was not a star aviator. Recently, he had been receiving grades of "average" on his semi-annual simulator check rides, and instructors had noted that he did not perform well under pressure. During his final flight, he made a number of minor errors that Luffingham and Laversha had had to correct—switches set wrong, faulty cross-checks, some awkward flying. He was slow-moving and methodical in a trade where some decisions must be made quickly.

The common assumption that the biggest airliners get the best pilots is not necessarily true. There are no merit promotions in the cockpit. Pilots move up solely on the basis of seniority in the company. The flight engineer on a weary 727 flying between Cleveland and Cincinnati might be an ex-Blue Angel with golden hands, while the captain of the same line's shiniest 747-400 Big Top en route to Bangkok might be an average Joe who started out in Cessnas and has managed to make it through 30 years without busting a regulation. That Stewart was flying one of British Airways' bigger and more complex aircraft was a reflection of the airline axiom "A captain is nothing but a copilot who's been with the company longer."

Yet why the Stewart case ever came to trial remains the subject of speculation. There is considerable feeling that British Airways was not sorry to see it happen, that Stewart was a loose cannon who could have made things awkward for an airline that places great value on its public image. Some feel that Stewart could have revealed some controversial company procedures. If Stewart were branded a criminal, it would effectively negate whatever damage he might do.

Stewart himself maintained that he was hauled into court "because British Airways and its supervisor the CAA condoned, wished, hoped, prayed, pressurized me to keep quiet" and that when he didn't they had no option but to publicly punish him. Others suspect empire-building within the CAA legal branch: this looked like a juicy case for an aspiring prosecutor to take public and demonstrate that even the flag carrier's jumbo jet captains dare not take on the aviation authority casually. "Glen was the first line pilot they could go after," Samantha Stewart opines.

One L-1011 captain, British albeit not a BA pilot, says, "My personal opinion is that the fleet manager who authorized November Oscar's approach with an unqualified crew should have been the one in court." Six weeks after the incident, British Airways announced that it was no longer granting bad-weather dispensations.

A senior British Airways captain told a London newspaper, "The aircraft was certificated for three crew who are supposed to cross-check each others' movements. The other flight-crew members are back flying again. [In fact, Brian Laversha had also resigned from BA.] So why is it Captain Stewart in the dock? Even if, at worst, it was a flying cock-up, how can that be construed as criminal? There but for the grace of God go a lot of pilots. Are we to be prosecuted for every little slip-up?"

But was it just a slip-up? My sympathies for Stewart were being sorely tried: I was tempted to say that the approach he'd flown was one that I'd have discarded and re-flown long before things got out of hand. Many professionals privately agreed that they'd have thrown it away as well, though Samantha Stewart characterized them as "a few clever Dicks who think they're too smart for it ever to happen to them."

In retrospect, Stewart might have demanded of the controller a longer final approach, which would have allowed the autopilot time to settle down. At eight in the morning, however, with night flights from all over the world converging on Heathrow, the rules have to be flexible. Stewart believed, but could not prove, that he'd been turned into the approach five miles behind the traffic he was following rather than the legal minimum of six. He was certainly forced to fly a hasty approach that may have been beyond the autopilot's capabilities. But the controller who put November Oscar in that position was not in the dock.

"They showed Glen the courtroom in advance, so he'd know what to expect," Samantha Stewart recalls, "but he was horrified. He was a terribly moral gentleman, and here was a dock where rapists had stood. They at least during the trial let him sit with the BALPA people [British Air Line Pilots Association, the union that had organized Stewart's defense], but during the sentencing he had to sit in the dock with a policeman. It was *awful* for him."

The trial took 11 days of extremely complex, technical testimony, before a jury of nonpilots with an average age of 26. Some jurors napped, not surprisingly, for the testimony detailing the sequence of checklists, button-pushing, instrument indications, and warning lights that marked November Oscar's progress down the Heathrow 27R ILS was a complex, dry recitation.

"It's a very, very complicated procedure," another 747 captain admits. "Flying that aircraft on automatic demands a workload that can actually be too much, especially if you don't have a good copilot." Stewart, in defense of his actions during the British Airways inquiry, had doggedly raised issue after issue, some of which danced around the question of exactly what had gone wrong and why. Accused, for example, of failing to file the necessary Mandatory Occurrence Report immediately upon landing, Stewart argued that be-

cause he had at least *initiated* the go-around from decision height and had landed successfully out of the second approach, it didn't constitute an "occurrence." Few agreed.

He argued that nowhere was it officially written that a proper go-around required that the airplane nose up at three degrees per second, which the airline claimed was the proper technique. (Well, it may not be written down, but it *is* the way to get the job done.) Stewart had applied back yoke that rotated November Oscar at a rate of less than one degree per second. He seemed evasive.

At one point, Stewart created a transcription of every oral call-out, checklist response, and radio transmission that company and CAA regulations required during the approach; by simply reading the script aloud nonstop, he showed that the entire routine took seven minutes. The approach itself had consumed only four, thus demonstrating that the letter of the law was impossible to follow. It was an interesting point, but nobody cared.

Stewart and his supporters made much of the fact that November Oscar was dispatched on its next leg, to Nairobi, before the recalcitrant autopilot could be examined for possible faults. And that four crucial pages from the airplane's maintenance log, which might have detailed repairs to that autopilot, are to this day missing. "There was a coverup," flight engineer Laversha insists. "That was made obvious by the fact that they sent the airplane right out again, and nobody was given an opportunity to examine it." (Yes, but if the autopilot is malfunctioning, isn't it the crew's job to detect it and compensate for it?)

Much of the trial revolved around arcane legal points, and Stewart himself was never called to testify on his own behalf. His BALPA lawyers believed that he would only continue to raise irrelevant issues, and that Stewart would have been better off pleading guilty and allowing them to seek mitigation of the charges. Stewart refused.

When the first verdict was announced, Stewart's many supporters in the courtroom cheered, for he was found not guilty of endangering people on the ground. ("Even the ushers were on our side," Samantha Stewart recalls.) The second verdict, however, branded him guilty of criminal negligence for endangering his passengers.

How he could be guilty of one and not the other baffled even a member of the prosecution team, who after the trial commented that the judgment was "bizarre." It is said that when the jury told the judge they'd come to a decision on the first charge but hadn't agreed on the second, he suggested with some impatience that they get their act together and wind the thing up, which perhaps prodded them to make an overly hasty assessment.

Still, Judge George Bathurst-Norman did seem to hold a degree of sympathy for Stewart. He turned down the CAA's demand that Stewart pay £45,000 in court costs and assessed only £1,500, and by refusing to levy a jail sentence he seemed to be signalling that the case should not have come to trial.

Stewart appealed the decision. The Avrisk Group, British aviation law specialists, prepared the application. Arthur Mitchell of Avrisk, also a former RAF and airline pilot, raised a variety of subtle legal points, most notably that the CAA had no legal right to bring such a prosecution. "In fact, the CAA itself was at fault," Mitchell later said, "for permitting a situation to exist in which the BA Flight Operations Manual contained a provision that Glen would be expected to use, by which it could authorize Glen to make the approach without a qualified copilot. The approach was actually illegal at the fault of British Airways, yet they were not charged.

"Had that provision not existed, Glen would have diverted to Frankfurt with cozy fuel reserves, to await better weather at London. It would not have been a long wait and would have given an opportunity to refuel, resulting in less stress on the eventual approach to London."

Stewart's appeal was summarily rejected.

"A mistake was made," says David Beaty, a former BOAC pilot and today one of the world's leading authorities on human factors in aviation, "but it was a collective mistake. Loads of other people made mistakes too, and that has not sufficiently been brought out."

In the end, I rejoined the Stewart camp, embarrassed to admit that I too would never have understood the pressures under which an airline captain operates if friends and acquaintances who do it every day had not made it obvious to me; that I too might have continued with the approach, convinced that it would be more expedient to sort it out while descending than to get myself into a box that might cost me a reprimand. A lot of lip service is paid to the myth of command residing in the cockpit, to the fantasy of the captain of the ship as ultimate decision-maker. But today the commander must first consult with the accountant.

"As a small boy, Glen lived near RAF Leuchars at the end of the war, and he used to watch the Coastal Command B-24s take off and land. That inspired him to become a pilot," David Beaty says. "I was flying Liberators out of Leuchars at the end of the war, and it makes me sad to think that perhaps one of those airplanes he watched was mine."

On December 1, 1992, three years and nine days after the November Oscar incident, Stewart left home without a word to his wife. He drove some nine hours to a beach near RAF Leuchars. There he ran a hose from his car's exhaust pipe through a nearly closed window. In a matter of minutes he was dead. He left no letter or any explanation.

MIKE JERRAM

Beware the Deadly Flying Circus

Above the Lines: A Complete Record of the Fighter Aces of the German Air Service, Naval Air Service and Flanders Marine Corps, 1914–1918 *by Norman L.R. Franks, Frank W. Bailey, and Russell Guest. Grub Street (London), 1994; distributed in the U.S. by Seven Hills Book Distributors. 320 pp., b&w photos, $49.95 (hardbound).*

COURTESY GRUB STREET

German aces in front of a Fokker Dr.I triplane wear the Pour le Mérite, better known as the Blue Max.

The publication of *Above the Lines* brings to a close the distinguished trilogy of World War I history that started with *Above the Trenches* (1990) and *Over the Front* (1992). While the earlier works focused on British, American, and French aces, *Above the Lines* concentrates on those in the German army and navy.

Each work in the trilogy portrays the emergence of the ace as a national hero; *Above the Lines* also describes the development of specialized fighter units and the flying circuses. Included in its histories of the 89 German army and navy fighter squadrons are biographies of 400 aces, which enumerate all relevant victory data. It turns out the Germans had the most accurate victory tallies, because over 90 percent of all World War I aerial combat took place on the German side of the lines. A special section completely annotates Manfred von Richthofen's 80 victories and confirms that—yes—the Red Baron was the war's greatest air fighter, truly deserving of his legend and status.

Like its predecessors, *Above the Lines* contains an abundance of new information and perspectives. For example, a review of Hermann Goering's 22 victories suggests that even though he owed his later rise and position in the Nazi Party to serving as the last commanding officer of von Richthofen's Flying Circus, toward the end of the war he rested on his laurels.

Above the Lines is an outstanding conclusion to a series of books that, individually and collectively, are the definitive work on World War I aviation heroes. The authors are to be commended for their achievement.

—Howard G. Fisher is the director of the San Diego Aero-Space Museum and the League of World War I Aviation Historians and an editor of Over the Front: The Journal of WWI Aviation Historians.

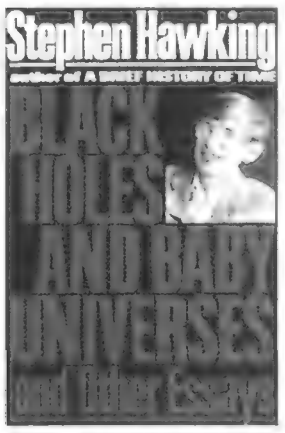
Black Holes and Baby Universes and Other Essays *by Stephen Hawking. Bantam, 1993. 182 pp., $21.95 (hardcover).*

If you are a reader who insists on beginning at the beginning, you will have to suffer through several unsatisfying chapters about Stephen Hawking's childhood before you start to be rewarded by *Black Holes and Baby Universes and Other Essays.* When you enter the realm of imaginary time and begin to sense the meaning of "a sum over histories" as a way to describe the world in which we live, Hawking's latest book offers an experience nothing short of thrilling. As you venture further and Hawking challenges you to think new thoughts along with him, evaporating black holes will seem almost obvious.

The heart of the book also offers insight into a human being who used to be bored with life until he was threatened with death. But it is Hawking's gift for revealing what he knows to be true without trying to translate his vision into overly simplistic terms that truly distinguishes this collection of essays. You may need to reread some of the paragraphs in order to savor their full flavor, but it's worth the effort. In the end,

you will find it easy to share Hawking's thoughts about the nature of cosmology and the strong possibility that the theory of everything is within sight.

When he suggested as much in his previous book, *A Brief History of Time*, Hawking was widely criticized. He tries to clarify the issue here and concedes that scientists will not be able to predict everything. The universe is, of course, far too complex. Instead, his theory deals with the foundations upon which the universe is built. Hawking shuns the view that the universe is a mystery, and he's right when he points out how few people are aware of the stunning progress scientists have made in their quest for knowledge.



Initially, some of Hawking's explanations may appear to defy common sense. After all, how could the universe have begun as a singular event—the Big Bang—in time, and yet have no beginning or end? Effortlessly, Hawking convinces us that before long, this odd notion of how the universe came to exist will be as widely accepted and understood as the fact that the Earth orbits the sun. In the end, however, he asks a question he cannot answer: "Why does the universe bother to exist?"

—Gerrit L. Verschuur is a research professor of astrophysics at Rhodes College in Memphis, Tennessee.

The Man Who Sold the Milky Way: A Biography of Bart Bok *by David H. Levy. University of Arizona Press, 1993. 246 pp., $35.00.*

In 1981, Bart Jan Bok replied to a request for biographical information from the editors of *Scientific American* by saying that since his retirement seven years earlier he had taken up his original childhood hobby: amateur astronomy. In fact, Bok had never lost the passion of his youth, and it was this enthusiasm, as well as his prodigious depth of knowledge, that made him a leading figure in professional astronomy for the greater part of a century.

Astronomers who knew Bok may hear echoes of his booming voice and wry wit in David Levy's *The Man Who Sold the*

Milky Way, for the author based much of the book on a series of interviews conducted in Bok's later years. Educated in the Netherlands, Bok arrived at Harvard College Observatory late in 1929. It was a great time to be young, star-struck, and in Cambridge, for though the world economy was on the rocks, Harvard's Observatory was enjoying a golden age. The cluster of red brick buildings on the hill was a magnet for up-and-coming astronomers from around the world, and Bok, whose mere presence could energize a conversation, became one of its most prominent attractions. For more than 25 years he mentored graduate students, wrote definitive treatises, and authored popular articles and textbooks. *The Milky Way*, which he co-authored with his wife Priscilla, became a minor classic, appearing in five editions over the decades.

After World War II, at an age when most scientists began to sink into administrative insipidity, Bok became one of the first astonomers to incorporate the new results of radio astronomy into his studies. But Harvard was moving in other directions, and by the mid-1950s Bok no longer felt welcome. He spent nine years developing the facilities of Australia's Mount Stromlo observatory, reveling in the spectacular southern hemisphere views of the Milky Way and becoming a well-known figure in the press and broadcast media. He returned to direct the rising astronomy department of the University of Arizona, from which he retired in 1974. Even in his administrative capacities, he never stopped doing astronomy.

David Levy has done a wonderful job of conveying Bart Bok's vital energy and his work. A more scholarly book may someday give a more dispassionate view of his place in the history of modern astronomy, but it could hardly do more to introduce readers to a man who made the heavens his life and the Milky Way his home.

—Laurence Marschall is a professor of physics at Gettysburg College in Pennsylvania.

Broken Wings of the Samurai: The Destruction of the Japanese Airforce
by Robert C. Mikesh. Naval Institute Press, 1993. 199 pp., b&w photos, $34.95 (hardbound).

There are two views of the matter. For those of us who dote on the fighting planes of yesterday, there's no sadder

sight than a warbird going to the scrap heap. Many people, though, would dance in the streets at the sight.

In any event, here's a book that chronicles the disabling, bulldozing, and torching of the Japanese army and navy air forces—11,000 airplanes—in the autumn of 1945. (To put that number in perspective, when Japan went to war, its aircraft inventory numbered 2,700.) Most of these airplanes had been intended for suicide missions against an expected American invasion fleet: frontline fighters and bombers, "Baka" piloted torpedoes, and pathetic biplane trainers, each with a drum of gasoline in the rear seat.

With 21 years in the U.S. Air Force, followed by another 21 years at the National Air and Space Museum, Robert Mikesh is a rare combination of curator and combat aviator. He has, in addition, a practical knowledge of Japan. His book begins with the best short history of that country's military aviation I have ever read, and it ends with a sightseer's guide to 105 Japanese warbirds (two of them are airworthy: a Mitsubishi A6M Zero flown by the Confederate Air Force in Texas, and another belonging to the Planes of Fame museum in California) that found homes with museums and foundations around the world.

—Daniel Ford wrote Flying Tigers: Claire Chennault and the American Volunteer Group *(Smithsonian Institution Press, 1992), which details the clash between the American Volunteer Group and Japanese army squadrons in 1941-1942.*

The Untouchables: Mission Accomplished *by Brian Shul and Walter Watson Jr. Mach 1, Inc., 1993. 215 pp., color photos, $43.00 (hardcover).*

Former SR-71 pilot Brian Shul has written an admirable successor to his award-winning *Sled Driver*. The earlier work demonstrated Shul's talent with a camera, which enabled him to capture stunning images of the Blackbird. His latest book, *The Untouchables*, offers more of the same, and also takes the reader along on an actual mission. It's the rare sequel—at least the equal of its predecessor, if not even better.

Actually *The Untouchables* includes two stories: the first is an account by Shul and his copilot, Walter Watson Jr., of a mission flying in support of the F-111 bombing raid of Libya in April 1986. Shul

and his backseater provide a riveting account of their six-hour mission, flying from England across the Mediterranean Sea to the target and back again.

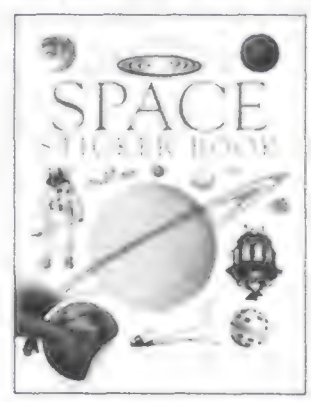
What really sets the book apart, however, is the second part of its story: commentary by those who designed, built, and maintained the SR-71. These civilian and military support team members speak with heartfelt pride, and most recall their experience with the Blackbird as the apogee of their careers.

The SR-71 is one of those airplanes that inspires strong emotion in those close to it, and at times the prose in *The Untouchables* is overwrought. But those who can't get enough of the Blackbird—or of a Blackbird's-eye view from 80,000 feet—won't be disappointed by this book.

—Bob McCafferty is a writer and photographer based in Fair Oaks, California. Formerly a television newsman, he covered the SR-71 at Beale Air Force Base.

FOR THE KIDS

Kids love stickers, and **The Ultimate Space Sticker Book** (*A Doris Kindersley Book, 1993, 8 pp., $6.95, paperback*) will please them with its colorful planets, spacecraft, and astronauts. **Plane Song** by Diane Siebert (*HarperCollins, 1993, 29 pp., $15.00, paintings by Vincent Nasta, hardcover*) celebrates the thrill of flight in verse and in paintings of a jumbo jet, crop duster, spy plane, and many others. For young space enthusiasts, **The Moon and You** by astronomer



E.C. Krupp (*Macmillan, 1993, 48 pp., $13.95, illustrations by Robin Rector Krupp, hardcover*) offers kids a lively introduction to our nearest celestial neighbor. Closer to home, **The Big Book for Our Planet** (*edited by Ann Durell, Jean Craighead George, and Katherine Paterson, Dutton, 1993, 136 pp., $17.99, hardcover*) is a collection of stories, poems, photographs, essays, and limericks about what makes our planet special.

CREDITS

The Crab Meat Bombed. O.H. Billmann is a frequent contributor to *Air & Space/Smithsonian* who lives in Simi Valley, California.

Gramps. Jonna Doolittle Hoppes teaches middle school in Huntington Beach, California.

Further reading: *I Could Never Be So Lucky Again*, James Doolittle, Bantam, 1991.

Grounded: The Aggressor Squadrons. Reina Pennington is the author of "Wings, Women, and War" (December 1993/January 1994).

The Great Lunar Quarantine. Brian Duff directed public affairs activities for NASA's Manned Spacecraft Center (now Johnson Space Center) in Houston during the Apollo era.

Further reading: *Where No Man Has Gone Before: A History of Apollo Lunar Exploration Missions*, William David Compton, NASA, 1989.

Single Stage to...Where? Preston Lerner is a freelance writer in Burbank, California. His last contribution was "Special Delivery" (February/March 1993).

Fierce to Win. Linda Shiner, the senior editor of *Air & Space/Smithsonian*, will gladly chase any gas balloon, anywhere, anytime.

Your Airbus Is Ready. Frequent contributor William Triplett's most recent article for *Air & Space/Smithsonian* was "Reality Check" (October/November 1993).

Gravity's Overdrive. Tony Reichhardt is a Washington, D.C. freelance writer. His article "Little Launches" appeared in the June/July 1993 issue.

"Okay, here's our flight plan."

CREDITS

Further reading: *Flight to Mercury,* Bruce Murray and Eric Burgess, Columbia University Press, 1977.

Journey Into Space: The First Thirty Years of Space Exploration, Bruce Murray, W.W. Norton & Co., 1989.

The November Oscar Incident. Stephan Wilkinson has been a pilot for 28 years and has flown 112 types of aircraft, from Stearman biplanes to business jets.

Where East Meets West. Frequent contributor Elaine de Man files her timeless observations from Alameda, California.

CALENDAR

February 27–March 2
12th Annual Aviation Symposium. Seminars, workshops, exhibits. Radisson Inn, Bismarck, ND, (701) 224-2748.

March 10–12
Fifth Annual Women in Aviation Conference. Sponsored by Parks College of St. Louis University. Disney's Contemporary Resort, Lake Buena Vista, FL, (618) 337-7575.

March 12 & 13
Sixth Annual Delight of Flight Airshow and Fly-In. Sponsored by Experimental Aircraft Association Chapter 908. Aerobatics, antiques, warbirds, homebuilts, hangar dance. St. Lucie County Airport, Fort Pierce FL, (407) 461-0346.

March 18–20
Phoenix 500 Air Races and Fly-In Convention. Three racing classes, aerobatics, static displays, golf outing, concert. Former Williams Air Force Base, Mesa, AZ, (602) 941-0061.

"The Satellite Sky" Update/40

These regular updates to "The Satellite Sky" chart will enable readers to keep their charts up to date. Additions can be clipped and affixed to the chart at the appropriate altitude.

New launches

90 to 300 MILES

Cosmos 2267
11-5-93 TT

300 to 630 MILES

Cosmos 2265
10-26-93 PL

Cosmos 2266
11-2-93 PL

6,200 to 13,700 MILES

GPS-23
10-26-93 CAC

21,750 to 22,370 MILES

DSCS 3-4
11-28-93 CAC

Gorizont 28
10-28-93 TT

Gorizont 29
11-18-93 TT

Intelsat VII-F
10-22-93 KOU

Meteosat 6
11-20-93 KOU

Solidaridad
11-20-93 KOU

Deletions

90 to 300 MILES

Progress M-19
down 10-13-93

Launched but not in orbit

90 to 300 MILES

Jianbing PRC photo recon	10-8-93	down 10-28-93
Progress M-20 CIS research	10-11-93	down 11-21-93
STS-58 U.S. research	10-18-93	down 11-1-93

300 to 630 MILES

STS-61 U.S. research	12-2-93	down 12-13-93

Inoperative but still in orbit

21,750 to 22,370 MILES

Aussat 1
Raduga 19

DATA: SAUNDERS KRAMER

FORECAST

In the Wings...

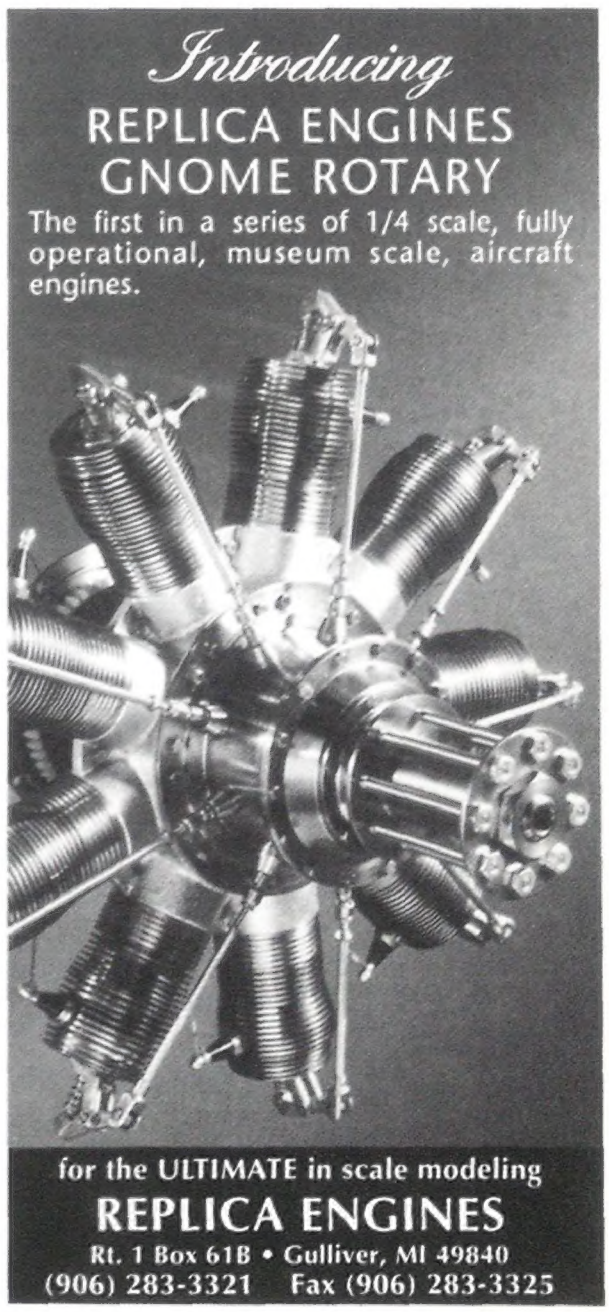
Skunk Works: The Truth Behind the Legend. The most thrilling military aircraft—the F-104 Starfighter, the U-2 and SR-71 spyplanes, the F-117 stealth fighter—all rolled out of the Lockheed Advanced Development Company. What did Lockheed have that other companies didn't, and does the LADC still have it?

An illustrated supplement will display the best of the Skunk Works pantheon.

The Bombing of Boise City. In 1943, as war raged in Europe, Boise City, Oklahoma, found itself under attack. A lone U.S. Army Air Force B-17 hit the town with five big ones before the crew realized their mistake.

Software Nightmares. In the highly automated business of space exploration, writers of computer programs that direct spacecraft must make sure that all their *i*'s are dotted and all their *t*'s are crossed.

From the Remorseless Deep. In March 1986 the USS *Preserver* located the crew cabin of the *Challenger* on the ocean floor 15 miles northeast of Cape Canaveral. The Navy diver who found the crew's compartment tells his story.



JOHN HEINLY

Where East Meets West

High on a hill outside London, overlooking a graceful wooded park, the Old Royal Observatory sits like a noble crown. Rising from the building are two copper cupolas, one topped by a five-foot orange ball sitting at the base of a spire. Every day at 12:55 p.m. the battered sphere inches its way to the top of the spire, and at precisely 1:00 p.m. it drops back down. In days gone by, navigators on ships in the Thames below used the descent of the ball to set their timepieces before sailing off for the farflung reaches of the Empire. Today, the sphere is just one of the curiosities featured at the Old Royal Observatory, or, in the local parlance, the "Royal Ob."

The observatory has been obsessed with time since it was founded over three centuries ago. Back then nautical navigation was a tricky business. The maps and charts seafarers carried were sometimes incomplete or altogether wrong. Making matters worse, though navigators could determine how far north or south they were by measuring the distance of one of the pole stars to the horizon, they had no idea how far east or west they were. As a result, the ships of the Royal Navy might wander for months looking for safe harbor, while the crew died of starvation and dehydration. Fortunately, King Charles II had among his several mistresses one Louise de Keroualle, who relayed an intriguing idea a French friend had suggested: longitude could be determined from the distance between the moon and various stars.

It was simple in theory. Every degree east or west translates into a time difference of four minutes. If you compare what time it is where you are with the time at a standard location, you can use the difference between the two times to calculate your longitude. To figure out your local time, you'd simply check the position of the sun or certain stars. To determine the time at the standard location, you could measure the angular distance between the moon and a star, then consult an almanac that would translate that distance into a time.

The problem was, no almanac listing such lunar observations had ever been compiled. In 1675 Charles II founded the Royal Observatory "for perfecting navigation and astronomy"—specifically, to get those crucial observations made and recorded. A site was selected in Greenwich, where the view of the stars was unobstructed by the soot and smoke of London. The facility, situated at a ruined castle, was built in part from materials scavenged from the Tower of London. Here, John Flamsteed, the first Astronomer Royal, spent night after lonely night for 44 years building a map of the sky.

The Old Royal Observatory, Greenwich, London SE10 9NF, England. Phone (081) 858-1167. Various admission packages available. April through September: Open Mon. to Sat., 10 a.m. to 6 p.m., Sun., noon to 6 p.m.; October through March: Mon. to Sat., 10 a.m. to 5 p.m. (GMT), Sun., 2 to 5 p.m.

Flamsteed lived on the premises, in a house designed by court architect Christopher Wren. On entering, you pass an exhibit of ornate 14th century brass astrolabes, instruments used to measure the positions of celestial bodies. Also displayed are sundials, globes, telescopes, and armillary spheres—models made up of rings representing the ecliptic, the tropics, and other spherical phenomena. As you wander on, you can see Flamsteed's red canopied bed and his long curly wig, sitting on a chest of drawers. A winding flight of narrow wooden stairs leads up to the Octagon Room, which has eight-foot-tall windows designed to accommodate the astronomer's telescopes. The room has been restored to look exactly as it did when Flamsteed, in his long flowing robes, used it to observe comets, eclipses, and other unusual celestial events.

Though Flamsteed made 50,000 observations, the immense lunar distance project had to be passed on to the next four Astronomers Royal; it wasn't until 1767 that the observatory finally finished compiling the first nautical almanac. But navigators found the book-based method complicated and imprecise. Fortunately, a better way to determine standard time had become available a few years earlier. In 1759 a clockmaker named John Harrison completed work on a bloated pocket watch-like device he called the H4 (it was the fourth in a series). The H4 was the first accurate timepiece designed for operation at sea. Harrison's chronometer was soon being mass-produced, and by 1833 seafarers were synchronizing them to the drop of the ball newly installed atop the Royal Observatory. Today, the museum keeps all four of Harrison's chronometers in working order.

In 1884, 25 countries agreed to make Greenwich Mean Time the basis for the international time zone system. They also agreed that the Prime Meridian for the world—the line representing zero degrees longitude—would be the one marked out by Astronomer Royal George Airy in 1851. The meridian passes through the observatory's cobblestone courtyard, where visitors can get a certificate documenting the date and exact Greenwich Mean Time when they stood at the place where east meets west.

By the 1940s, celestial observations at Greenwich were being hindered by the increasing pollution and lights from London. The observatory was moved to Sussex and later to Cambridge; the original facility was made into a museum.

Today, satellite-based global positioning systems can tell you precisely where you are, anytime, night or day. Quartz crystal and atomic clocks work without a single reference to the movement of Earth or the stars. All are on display at the Royal Ob, where the lesson of centuries of study is best summed up in the inscription on an exquisite 18th century filigreed astrolabe: "The aim of this is so that something may be left of us, for we know that we do not live forever."

—Elaine de Man

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